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**THE FAUNAS OF THE CAMBRIAN PARADOXIDES
BEDS AT MANUELS, NEWFOUNDLAND**

(Princeton University Contribution to the Geology of Newfoundland — No. 7)

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in candidacy for the degree of Doctor of Philosophy*

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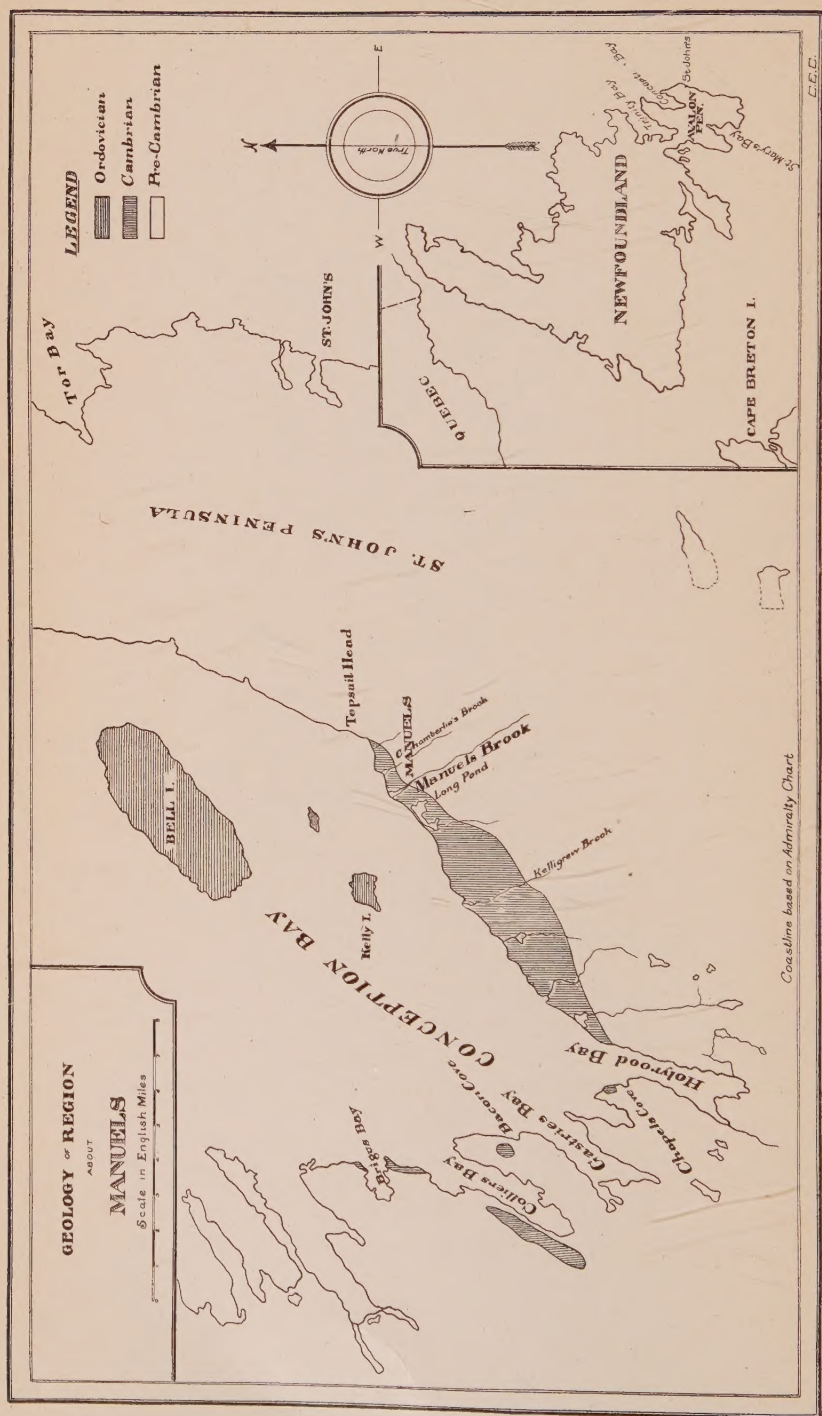


FIGURE 1. Map showing the general geology about Manuels. The small inserted map shows the location of the area covered by the main map. (See pp. 19-23)

I. INTRODUCTION AND ACKNOWLEDGMENTS

The Paradoxides beds of the famous Cambrian section at Manuels, Newfoundland, whose stratigraphical and faunal succession are described in this paper, are of unusual interest because a large proportion of the many species of fossils which they contain are found also in the contemporaneous beds of northwestern Europe.

The description of the beds here presented is based on field work done at Manuels by members of four geological expeditions from Princeton University, and on laboratory studies pursued by the writer at that university and other institutions in eastern North America.

The writer makes grateful acknowledgment of the encouragement and financial support that have been extended to him in this research by the Department of Geology and the Graduate School of Princeton University, and tenders his sincere thanks to the many friends who have placed information or collections at his disposal or have assisted him in the field. He is indebted to Dr. A. O. Hayes, Professor N. C. Dale, of Hamilton College, and Professor A. F. Buddington, of Princeton, for data collected by them while members of the Princeton field parties in Newfoundland, to Professor A. H. Phillips, of Princeton, for numerous chemical analyses and mineralogical determinations, and to Dr. E. C. Cairnes, lately Fellow in Geology in the same institution, for drawing and lettering his maps. Professor Gilbert D. Harris, of Cornell University, loaned him the Hartt Collection from the Paradoxides beds of New Brunswick; Professor Percy E. Raymond, of Harvard University, and Professors Charles W. Brown and Richard M. Field, of Brown University, afforded facilities for the examination of

collections in their care and loaned fossils from Newfoundland and New Brunswick and Professor Raymond conducted him to the famous *Paradoxides harlani* quarry at Braintree, Massachusetts, and assisted in obtaining a collection from there. Mr. James P. Howley, the late director of the Geological Survey of Newfoundland, opened the Newfoundland Survey's Cambrian collections for his examination; Professor W. A. Parks allowed him to study the Matthew Collection of New Brunswick and Newfoundland types in the Royal Ontario Museum of Palæontology; and Dr. Charles D. Walcott gave permission to examine the wonderful series of specimens from the *Paradoxides* beds of many countries that he has gathered together at Washington. The late Dr. G. F. Matthew and Mr. William McIntosh, of St. John, guided him to a number of the Cambrian localities in southern New Brunswick, and presented a valuable collection of fossils. Professor George H. Perkins supplied information about the Cambrian of Vermont; Mr. L. D. Burling furnished a list of the species from the *Paradoxides* beds of Newfoundland and eastern Canada that are represented in the collections of the Canadian Geological Survey; and Dr. Charles E. Resser, of the United States National Museum, provided much valuable information, especially about Cambrian bibliography.

Most of all, the writer desires to express his appreciation to his wife, for her constant encouragement, helpful criticism, and efficient aid in the field and laboratory; and to Professor Gilbert vanIngen, of Princeton, for the use of his large library, assistance in the preparation of the photographic illustrations, and a great deal of invaluable guidance and advice.

II. PREVIOUS WORK AND LITERATURE

J. B. Jukes, who made the earliest official geological survey of Newfoundland and was probably the first man to study and classify the rocks of the Conception Bay region, noted the presence of shales at Manuels, and referred them to the "Belle Isle" division of his "Upper Slate Formation."* (See column I of Table I, p. 12.) He found no fossils in these shales, and therefore could not determine their age. He judged from their appearance that they were very old, although he knew from their stratigraphic position that they were younger than most of the other rocks of the district. (Jukes, 1842, vol. II, pp. 245, 249, 275, 329; 1843, pp. 51, 55, 81, 135, and map.)

Alexander Murray, who was the first director of the second official Newfoundland survey, appears to have been the next geologist to work at Manuels. The first published result of his investigations was probably incorporated in Logan's "Geological Map of Canada," which appeared in 1865, and in which the beds at Manuels were mapped as belonging in the "Calciferosus" division of his "Lower Silurian" "Quebec group" (Logan, 1865, p. 15, pl. 1). The next reference to the beds at that locality was in Murray's report of progress for 1866 (Murray and Howley, 1881a, p. 75) in which Murray stated that a "very good section of the more recent formation" (Jukes' "Upper Slate Formation") was exposed "on Manuels"† Brook, at Topsail Head, and at Kelly's Island." He wrote that "the obscurity or absence of organic remains" rendered it "unadvisable to express too decided an opinion" as to the age of this "forma-

* All terms and statements included in quotation marks in the present paper are quoted verbatim from other authors, and are used in the sense in which those authors used them.

† Various spellings of Manuels occur in geological literature. The spelling employed in the present paper is the one that was used by Mr. Howley on the 1907 official geological map of Newfoundland. (Howley, 1907.)

tion"; but added, in a foot-note, that a fossil, which appeared to be of earliest "Silurian" age, had been discovered in its upper beds. In his report for 1868 he presented a hypothetical section of the "Lower Silurian (Potsdam)" strata of the Conception Bay basin, showing the beds arranged in what he thought was probably nearly their true order (Murray and Howley, 1881a, pp. 156, 157, and plate facing p. 160); and in his report for 1870, he included a generalized composite section of all of the "Primordial Silurian" strata of southeastern Newfoundland that he and his then assistant, Mr. J. P. Howley, had discovered up to that time (Murray and Howley, 1881a, pp. 237-239). Summaries of these sections are given in columns 2 and 3 of Table I of the present paper.

Murray included the beds at Manuels in both his 1868 and his 1870 "Silurian" sections, but he had never succeeded in finding any fossils in them, and was therefore not certain that his estimate of their age was correct. In 1874 he arranged to have T. C. Weston, then collector for the Canadian Geological Survey, visit Manuels and make a thorough search for the needed paleontological evidence. Weston's search was successful. He found fossils in the Paradoxides beds in the valley of Manuels Brook, and identified the first one he discovered as a species of "Microdiscus" that was common in the Paradoxides beds of New Brunswick (Weston, 1896, p. 153). The fossils that he collected were apparently sent to Ottawa, for four years later J. F. Whiteaves, then paleontologist of the Canadian Survey, referred most of them to species that had previously been described from New Brunswick, and correlated the beds containing them with the "St. John's Group" of that province (Whiteaves, 1878).

In 1884 Dr. C. D. Walcott correlated the Paradoxides beds at Manuels with those at St. John, New Brunswick, and with "the lower part of the Menevian, or possibly with portions of the Harlech and Longmynd groups" of Great

Jukes 1842 and 1843 (Jukes, 1842; 1843)		Murray Report for 1868. (Murray and Howley, 1881a, pp. 156, 157)		Murray and Howley Report for 1870. (Murray and Howley, 1881a, p. 237)		Matthew 1886 (Matthew, 1886)	
Upper Slate Formation.	Variegated Slates.	Belle Isle Shale and Gritstone. (potsdam)	Sandstones and shales of Great Bell Isle.	Sandstones and shales of Bell Island.	Formation	Fauna of the Olenus division.	
			Little Bell Isle sandstones and shales.	Sandstones and shales of Little Belle Island and adjacent part of Conception Bay.			
			Kelly's Island sandstones and shales.	Kelly's Island sandstones and shales.			
			Brown, black, red and green shales, con- taining Paradoxides bennetti in upper part.	Red, green, and black shales, and gray limestones, containing Paradoxides bennetti.		Horizon of Paradoxides Davidis. Horizon of Paradoxides Tessini. Horizon of Paradoxides spinosus (?). Horizon of the Conocoryphinae.	
Lower Silurian			Topsail limestone.	Topsail limestone.	Primordial		
			Conglomerate and black and brown shales (seen at Manuels).	Red, green, and blackish shales. Conglomerate (seen at Manuels). Red and green shales and lime- stones.			

Table I.

Walcott May, 1888 Walcott, 1888a, p.399)	Walcott October, 1888: (Walcott, 1888b)	Walcott 1889 (Walcott, 1889a, p.383)	Marcou 1890 (Marcou, 1890, p. 226)	Walcott 1891 (Walcott, 1891a, p.548)	Matthew 1896 (Matthew, 1896 pp. 193-194)
	Belle Isle, Upper Cambrian, (Olenus)	Belle Isle, Upper Cambrian, (Olenus)		Belle Isle, Upper Cambrian, (Olenus)	
Newfoundland, Lower Cambrian, with Paradoxides.	Avalon, Middle Cambrian, (Paradox- ides)	Avalon, Middle Cambrian, (Paradoxides)	Bohemian, or Paradoxides zone, late Middle Taconic.	Avalon, Middle Cambrian, (Paradoxides)	Sub-zone of Paradoxides Davidis. Sub-zone of Paradoxides Abenacus (doubtful). Sub-zone of Paradoxides Rteminicus.
	Terra Nova, Lower Cambrian, (Olenellus)	Terra Nova, Lower Cambrian (Olenellus)	Scandinavian, or Holmia zone, early Middle Taconic. Esthonian, or Schmidtia zone, late Lower Taconic.	Placentia, Lower Cambrian, (Olenellus)	

Table showing the ways in which different authors have classified the early Paleozoic rocks

in the Present Paper.

visions, see Table III, p.)

that are known to occur
out Conception and Trinity
in lower beds.

and other fossils.

s pisiformis obesus, "Olenus",
other fossils.

us pisiformis.

fauna of unidentified forms.
y a "Paradoxides forchhammeri

3-125 of the present paper
p.).

6-92 of the present paper
p.).

35 of the present paper.
p.).

iferous beds.

th Catadoxides magnificus
er fossils.
th Protolenus and other
s.

th Callavia bröggeri and
ossils. Some of the beds of
vision may be of pre-Callavian
ey appear to contain no
tes, but hold a "Coleoloides".

Britain (Walcott, 1884, p. 13), and in the following year Dr. Matthew correlated them with the "Acadian" beds of St. John, New Brunswick and the Solva of Great Britain (Matthew, 1885, pp. 121 and footnote, and 122).

In 1886 Dr. G. F. Matthew tentatively divided the "Paradoxides" beds of Newfoundland into five "horizons," as follows:

5. "Horizon of Paradoxides Davidis."
4. "Horizon of Paradoxides Tessini."
3. "Horizon of Paradoxides spinosus (?)."
2. "Horizon of the Conocoryphinae."
1. "Horizon of Agraulos strenuus."

He stated that the "Horizon of the Conocoryphinae" occurred at Manuels, and that the others were found at other localities on the shores of Conception, Trinity, and St. Mary's Bays (see map, Fig. I). He listed the species that had been recorded from Manuels by Whiteaves in 1878, and added a number of other forms which he had found in material from the same locality that had been sent to him by Mr. Howley (Matthew, 1886b, 1887). His "Horizon of Agraulos strenuus" has since proven to be of pre-Paradoxidian age. Two years later he correlated the "Shales of Manuel R." with "Division" 1c of the "St. John Group" of Canada, the upper part of the "Upper Sparagmite formation—Etage 1b and c" of Norway, the upper part of the "Lower Paradoxides Beds" of Sweden, and doubtfully with the upper part of the "Solva group" of Great Britain (Matthew, 1888a, p. 25). At this time he considered that the "horizon of Conocoryphe at Manuel Brook" was older than the "limestone beds of Topsail and Brigus, in Conception Bay," because Murray, unable to find any fossils at Manuels, had placed the beds of that locality below the limestone of Topsail and Brigus in his stratigraphic section (Matthew, 1888d, p. 74).

In the May, 1888, issue of the American Journal of Science, Dr. Walcott applied the term "Newfoundland" to the Paradoxides beds "of the St. John's area of Newfound-

land" (Walcott, 1888a, p. 399). He apparently intended his new term to apply to all the known Paradoxides beds of southeastern Newfoundland. This name appears to be the earliest one applied to these beds alone; and, if it does not prove to have been used previously in any other sense, should be used for these beds in the future.

In the summer of 1888, Dr. Walcott found an "Olenellus fauna" in beds beneath the Paradoxides beds at Manuels. He announced his discovery a few weeks later in London, at the meeting of the fourth International Geological Congress (Walcott, 1888b, 1891c). As most American geologists had believed, up until that time, that "Olenellus" belonged stratigraphically above Paradoxides, this discovery aroused a great deal of interest, and Manuels quickly became one of the famous Cambrian localities of the world. Dr. Walcott published a brief description of the section at Manuels, and gave lists of the fossils that he had found there. From the Paradoxides beds, which he divided into three zones, he recorded thirty species, some of which he recognized as forms that were characteristic of the Paradoxides beds of New Brunswick or Wales (Walcott, 1889a, pp. 378-381). He referred the beds above the "Olenellus zone" in the Manuels Brook section to a new "terrane," the "Avalon* terrane" (Walcott, 1888b; 1889a, p. 383; 1891a, p. 548; 1891b, pp. 66, 306; 1891c); but he later (Walcott, 1899, p. 219) ceased using the term "Avalon" for these rocks, and applied it to the great group of pre-Cambrian sediments that underlies the Cambrian in southeastern Newfoundland, in which sense it is now generally employed. (See Van Hise and Leith, 1909, pp. 43, 99-100, 518-529; Willis, 1912, pp. 14, 16; Buddington, 1919, p. 451.)

In 1889 Dr. Walcott (1889b, p. 445) described a tiny trilobite, which he named "Karlia minor," from the beds containing Paradoxides davidis at Manuels. He later

* Spelled "Avalan" when first used (1888); but this was probably due to a typographical error, as the name was taken from the Avalon Peninsula and was spelled "Avalon" by Dr. Walcott in all his subsequent papers.

referred this species to the genus *Corynexochus* (Walcott, 1916a, p. 224; 1916b, p. 319).

In 1890, Jules Marcou correlated the Paradoxides beds of Newfoundland with those of New Brunswick and with "the lower part only of the Paradoxides zone at Braintree," Massachusetts (Marcou, 1890, p. 226). In the same year, Dr. Matthew (1890, p. 137) correlated the uppermost of Dr. Walcott's three Paradoxides zones at Manuels with the Menevian of Wales, "Etage 1d" of Norway, and the "Upper Paradoxides Beds" of Sweden; and the two lower zones with the "Lower Paradoxides Beds" of Sweden, a part of the "Upper Sparagmite-Etage 1c" of Norway, and a part of the Solva of Great Britain. In 1891 he (Matthew, 1891) correlated the Newfoundland faunas with similar ones elsewhere, in the manner shown in Table II of the present paper. In the same year Dr. Walcott published the horizontal section of the beds at Manuels that is reproduced in Figure 2a of the present paper (p. 16), and gave a resume of the work that had been done up to that time on the Paradoxides beds and faunas of Newfoundland (Walcott, 1891a, pp. 528, 548, 554, 555, 565, 582, 583, and figs. 51 and 52; 1891b, pp. 50-55, 78-80, 113, 257-262, and 374; 1891d, pp. 533, 548, fig. 75, and pl. 42).

TABLE II. Dr. G. F. Matthew's 1891 correlation of the Paradoxides faunas of southeastern Newfoundland with those of other regions. Copied from Matthew (1891, p. 265)

	a	b	c	d	e	f
	<i>P. Oelandicus</i>	<i>P. rugulosus</i>	<i>P. Tessini</i>	<i>P. Davidis</i>	<i>P. Forchhammeri</i>	<i>P. Lævigatus</i>
Sardinia (Italy) -----	*?	*?				
Montagne Noire (France) ---		*				
Bohemia -----		*	*			
Wales -----	*?	*	*	*		
Sweden and Norway -----	*	*	*	*	*	*
Newfoundland -----		*	*	*		
Acadia (N. Brunswick) -----	*	*	*			
Massachusetts -----		*				

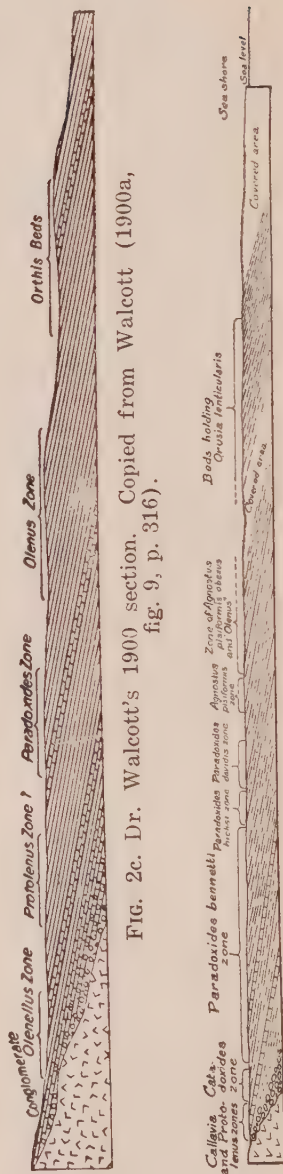
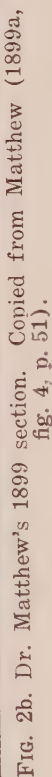
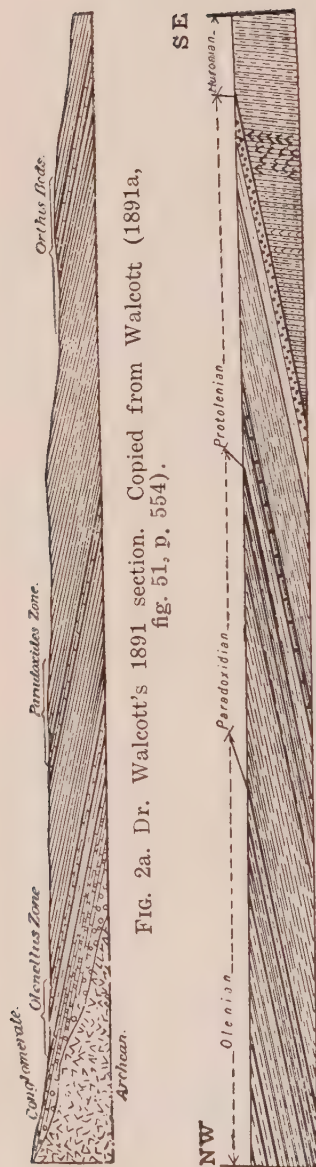


FIG. 2d. Section based upon the work of the Princeton field parties. The beds shown are those that outcrop in the valley of Manuels Brook.

FIGS. 2a-d. Sections of the Cambrian beds at Manuels, by Dr. G. F. Matthew, Dr. C. D. Walcott, and the writer, to illustrate the increases in our knowledge of the limits of the "Olenellus," "Protolenus," "Paradoxides," and "Olenus" zones at that locality. Scale of all the sections, about 1,500 feet to 1 inch

In 1896 Dr. Matthew subdivided the Paradoxides beds of Newfoundland as follows (Matthew, 1896) :

3. "Sub-zone of *P. Davidis*."
2. "Sub-zone of *P. Abenacus*" (doubtfully identified in Newfoundland).
1. "Sub-zone of *P. Eteminicus*."

He recorded from the "sub-zone of *P. Davidis*" at Manuels several species not previously known from that locality, one of which he described as a new form, naming it "*Plumulites manuelensis*."

In 1898 Dr. Walcott described a new species of brachiopod, "*Obolus (Lingulella) fragilis*," from the "Middle Cambrian" shales "on Manuels Brook" (Walcott, 1898, p. 404). In the same year Dr. Matthew visited Manuels, and soon afterward published the horizontal section that is reproduced in Figure 2b of the present paper. He stated that the dividing line between the "Olenian" and "Paradoxidian" parts of his section was drawn arbitrarily (Matthew, 1899a, pp. 50-52, fig. 4). He recorded an *Erinnys* "from the Paradoxides Davidis sub-fauna at Manuels Brook," and "*Atops trilineatus*" from an unknown horizon, which he thought might be the "Davidis zone," at the same locality (Matthew, 1899c, pp. 89-95).

In 1899 Dr. Walcott visited Manuels a second time. His account of this visit, published in 1900, included a description of the beds which seemed to him to mark the lower and upper limits of the "Paradoxides zone" in the brook valley, and contained, as one of its illustrations, the horizontal section that is reproduced here as Figure 2c (Walcott, 1900a, pp. 313-317, 329-331, and figs. 9 and 10.)

In 1902 Dr. Walcott recorded a brachiopod, "*Acrotreta misera* Billings" from the beds of the "Paradoxides

zone" at this locality (Walcott, 1902, pp. 590, 591). In 1905 he described a new species of brachiopod, "*Plectorthis papias*," from the same beds (Walcott, 1905, p. 268). He afterward referred the latter species to the genus *Eoorthis* (Walcott, 1912, p. 785).

In 1910 Professor Charles Schuchert wrote of the Paradoxides beds as follows: "In southern Newfoundland, on Manuels brook, the Acadic begins with a conglomerate having pebbles holding fossils of the Georgic strata below (Walcott, 1900, p. 315). Above this layer, which is 18 inches thick, follow argillaceous shales having a depth of 170 feet. These are succeeded by a thin limestone zone marked by the presence of Paradoxides, the latter extending 66 feet higher in a series of shales interbedded with limestone. Here occurs Paradoxides davidis and *P. bennetti*. Apparently a stratigraphic hiatus exists above these beds, followed by the Olenus fauna." (Schuchert, 1911, p. 522.)

In 1912 Dr. Walcott, in his monumental monograph on the Cambrian Brachiopoda, described and figured all the brachiopods known to occur in the Paradoxides beds at Manuels and listed the other fossils that he had recorded from those beds in 1889 (Walcott, 1912, pp. 140, 141, 161, 162, 170, 392, 393, 496-500, 647-649, 653, 654, 695, 785, and plates XXIII, XXIX, LXXII, XCI). In the same year Dr. B. N. Peach, referring to Dr. Walcott's description of the Manuels Brook section, wrote "In Southern Newfoundland Walcott showed that the base of the Middle Cambrian division is marked in Manuel's Brook by a conglomerate containing fossils of the lower or Georgian terrane, thus indicating elevation and erosion of the Lower Cambrian rocks. Higher up the strata yielded Paradoxides davidis and *P. bennetti*" (Peach, 1912, p. 455).

During the summers of 1912, 1913, and 1914, Professor Gilbert vanIngen, Dr. A. O. Hayes, Dr. N. C. Dale, Dr. A. F. Buddington, and the writer studied and mapped the rocks at Manuels and collected many fossils there, including more than 3,000 from the Paradoxides beds. In 1914, Professor

vanIngen (1914b) issued the "Table of the Geological Formations of the Cambrian and Ordovician Systems about Conception and Trinity Bays" that is reproduced in Table III (p. 20) of the present paper, and Dr. Dale gave a brief description of the manganiferous beds which underlie the lowest known Paradoxides beds of that region (Dale, 1914). The complete results of Dr. Dale's investigation of this "manganese zone," which were published soon afterward, included a detailed description of the "zone" at Manuels (Dale, 1915, pp. 371-409, and figs. 1-29).

In 1919 the writer examined foot by foot the Paradoxides beds in the valley of Manuels Brook, and, with Mrs. Howell's assistance, collected some 7,000 fossils from them. Summaries of two preliminary papers based largely on the work of this and the previous Princeton expeditions were published in 1920 and 1922 (Howell, 1920a; 1920b, 1922).

In 1920 Dr. Walcott recorded *Protospongia fenestrata* Salter from "the black shales of the Paradoxides hicksi zone" at Manuels (Walcott, 1920, pp. 305, 306).

III. GENERAL GEOLOGY OF THE REGION ABOUT MANUELS

The major features, and some of the minor details, of the geology of the Avalon Peninsula, on which Manuels is situated, have been described and mapped by Jukes (1839, pp. 1-4, 6-16, 27, 28; 1840a, pp. 104-108; 1840b, p. 1; 1842, pp. 219-226, 245, 249-254, 256-276, 321-334; 1843, pp. 25-32, 51, 55-60, 62-82, 127-140, map, and sections 1-8), Murray and Howley (1881a, pp. 138-179, 199-205, 232-249, 279-297, 478-483, 532-536; 1881b; 1918, pp. 4-32, and maps), Walcott (1889a, pp. 378-381, 388; 1891a; 1891b, pp. 50-55, 113, 257-262, 273, 360-361, 365, pl. II; 1891c; 1899, pp. 201, 218-221, 230-231; 1900a; 1900b), Chamberlin (1895), Matthew (1899a, pp. 45-52, figs. 3 and 4), van Hise and Leith (1909, pp. 43, 99, 100, 518-520), vanIngen (1914a, 1914b), Hayes (1914; 1915), Dale (1914; 1915),

and Buddington (1914, 1916, 1919). Most of the information contained in this chapter has been taken from the works of these authors.

The peninsula is composed of a complex of Pre-Cambrian igneous and sedimentary rocks, with scattered remnants of a once wide-spread blanket of sediments of Cambrian, Lower Ordovician (and perhaps also Ozarkian) age clinging to it in the places where they have been protected from erosion. (See map, fig. 1, p. 8.) The Pre-Cambrian rocks include interbedded rhyolite and basalt flows, with corresponding breccias and tuffs, and volcanic dust beds, shales, sandstones, and conglomerates (the Harbour Main volcanics*; total thickness unknown); thin-bedded, greenish-gray, dense slates, feldspathic sandstones, and conglomerates (named by Dr. Walcott the Conception slates; estimated to be about 3,000 feet thick); green and reddish slates (Dr. Walcott's "Torbay slates"; estimated thickness, 3,300 feet); dark brown and blackish slates (Dr. Walcott's "Morable slates"; estimated thickness, 2,000 feet); reddish-brown and green feldspathic sandstones and conglomerates, with intercalated shale beds (the "Signal Hill sandstones" of Jukes; estimated by Dr. Buddington to reach a thickness of 10,000 feet); reddish, greenish, and white sandstones and quartzites (Dr. Walcott's "Random terrane"; supposed to be 1,000 feet thick); and intrusives of gabbro, granodiorite, granite, granophyre, quartz syenite, aplite, rhyolite porphyry, and diabase. It is probable that the Harbour Main volcanics are the oldest members of this group; and that they are succeeded in age, from oldest to youngest, by the Conception, Torbay, and Morable slates, and the Signal

* Dr. Buddington named these rocks the "Avondale volcanics" in 1916 (Buddington, 1916, map, p. 131). "Avondale" was, however, used by Frazier as a formation name in a different sense many years earlier (Frazer, 1883, p. 307). It becomes necessary, therefore, to assign a new name to the Newfoundland volcanics; and, at Dr. Buddington's suggestion, "Harbour Main" is here proposed. The rocks are well developed near Harbour Main, Conception Bay.

N. E. AMERICA		SERIES NAME	FORMATION NAME	NUMBER	KIND OF ROCK	ORE ZONE	INDEX FOSSILS	WESTERN EUROPE
LOWER ORDOVICIAN	Canadian	Wabana	Gravel Head	K 2 K 1	Black shale Phosphorite		Lingula fraseri, sp. n. Schizocrania striata, sp. n. Westonia, sp.	? Llandeilo
			Upper Ore Bed	J 4	Oolitic hematite	5	Disconformity Lingula, Ilesucri Westonia Schizocrania striata, sp. n.	Upper Arenig
				J 3	Sandstone and shale		Cruziana	
				J 2	Phosphorite		Schizocrania hayesi, sp. n. Lingula, sp. Westonia, sp. Synholonotus chambersi, sp. n.	
				J 1	Chamosite slate		Disconformity Hemigraspis cantleyi, sp. n. Ptilocephalus ?	
			Scotia Ore Bed	H 4	Oolitic hematite	4	? Disconformity Synholonotus chambersi, sp. n. Boring Algae Cruziana similis	Middle Arenig
				H 3	Grey shale		Didymograptus nitidus Synholonotus chambersi Orthoceras	
			Pyrite Bed	H 2	Pyrite nodules in grey shale	3	Didymograptus	
				H 1	Phosphorite		Helmserenia wabana, sp. n.	
							Disconformity	Armorican
	Bretonian	Bell Island	Dominion Ore Bed	G 10	Oolitic hematite	2	Boring and other Algae Lingula hawkei	
				G 9	Sandstone and shale		Lingulobolus affinis Pizarroa terranova	
			Redmond	G 8	White sandstone			
				G 7	Grits and shales			
			Eastern Head	G 6	Ferruginous sandstone with oolitic hematite and some shales	1	Obolus burrowsi, nov. Sphaerobolus fimbriatus, nov. Lingula murrayi, Billings Lingulella lillingsi Lingulella bella	Lower Arenig
			Beach	G 5	Sandstones and shales			

Deep Kill Bed 2

Canadian

LOWER ORDOVICIAN

Bretonian

Lower Arenig

Armorican

Middle Arenig

Upper Arenig

WESTERN EUROPE

? Llandeilo

[illegible]

TABLE 3. Reproduction of the Cambrian and Ordovician parts of Professor van Ingen's 'Table of the Geological Formations of the Cambrian and Ordovician Systems about Conception and Trinity Bays, Newfoundland, and their Northeastern - American and Western - European Equivalents'. The Pre-Cambrian part of the table has been omitted. Copied from van Ingen (1914b).

Hill and Random sandstones; although the Conception slates may be in part contemporaneous with the Harbour Main volcanics. The Conception, Torbay, Momable, Signal Hill, and Random shales, sandstones, and conglomerates have been grouped together by Dr. Walcott in the "Avalon" series" (Walcott, 1899, pp. 218-220; 1900b). This sedimentary series has been referred by Dr. Walcott to the Algonkian, and Dr. Buddington has stated that the volcanic and intrusive igneous rocks were also possibly formed during that era.

Dr. Buddington has interpreted the beds of the Signal Hill formation as "dominantly subærial fluviatile deposits," formed "in a subarid climate"; those of the Momable as "well-decomposed marine sediments with traces of organic life"; and those of the Conception, as deposits composed of "materials derived from rocks resembling the Harbour Main volcanics, swept into the sea in a comparatively fresh, unaltered condition."

The Cambrian and overlying Ordovician (and perhaps Ozarkian) beds are shales and sandstones, with a few limestones and limy shales in the Cambrian. They probably aggregate some 10,000 feet in thickness (vanIngen, 1914a), and are not known to be divided by any angular unconformities. They are cut by dykes of basalt at some localities. The pre-Paradoxides beds of the Cambrian are conglomerates and sandstones, red and greenish shales (often with many nodules of impure limestone), and thin reddish and grayish limestones: some of them are manganiferous. They include the "Etcheminian" and "Hanfordian"* series of Professor vanIngen's 1914 table (see table III).

So far as the author is aware, these "Etcheminian" and

* The terms "Etcheminian" and "Hanfordian" were first applied to New Brunswick Cambrian rocks (Matthew, 1888b, p. 1; 1888d, p. 72; Walcott, 1891b, p. 360). The Newfoundland "Hanford formation" of the "Hanfordian series" of Professor vanIngen's 1914 table is possibly not the exact equivalent of the New Brunswick "Hanford," as that was originally described by Dr. Walcott.

"Hanfordian" sediments are the only ones of Paleozoic age that are known to have been laid down directly upon Pre-Cambrian rocks in the region about Manuels. Wherever the contacts between these Cambrian and Pre-Cambrian rocks are known, they appear to be either unconformities or disconformities. The Paradoxides beds (Professor van Ingen's Manuels series) are gray, brown, and black shales, with thin beds of limestone and limy nodular shale. The beds that overlies the Paradoxides beds along the southeastern shore of Conception Bay, most or all of which belong in Professor vanIngen's Elliott Cove series, are "grey and black shales with cone-in-cone concretions and thin-bedded sandstones" (VanIngen, 1914b). Some of these beds are of Upper Cambrian age, and some may be Ozarkian or earliest Ordovician. The three islands that lie out in the middle of Conception Bay (Bell, Little Bell, and Kellys islands) are composed of beds which have been referred to the Lower Ordovician—the Bell Island and Wabana series of Professor vanIngen's 1914 classification. They are light and dark colored shales and sandstones, with several beds of primary hematitic iron ore. Beds probably referable to Professor vanIngen's Clarendville series, which belongs stratigraphically between the Elliott Cove and Bell Island series, presumably underlie Conception Bay between the islands and the mainland. No angular unconformity is known to exist anywhere within this great stratigraphic section.

The main structural features of the Peninsula of Avalon are a series of folds and faults, whose axes lie in a general NNE.-S.SW. direction. The Pre-Cambrian rocks were folded before the deposition of the Lower Cambrian sediments upon them. Later the Pre-Cambrian, Cambrian, and Ordovician rocks were folded, faulted, and tilted. The masses of Cambrian and Ordovician sediments that were folded or faulted by these movements into situations where they were protected from erosion are the ones that have been preserved until the present day. One of these favored masses underlies much of Conception Bay in such a

way that a few small patches along the western and southern sides of the bay and a narrow strip along the eastern shore are the only parts of the mass that project above sea-level. It is in the narrow strip along the eastern shore that the exposures at Manuels are situated.

Dr. Buddington (1919, p. 454) has described the structural features of the Conception Bay basin as follows: "The core of a major anticline composed of complexly faulted and folded beds of the volcanic series, cut across at a small angle by a stock of granodiorite, is exposed at the head of Conception Bay. At Chapel Cove its eroded surface is overlain by beds constituting the south end of a northward-pitching synclinal fault block of Cambrian sediments, in which Conception Bay is excavated. We have here apparently the phenomenon of the location of a younger syncline in sediments deposited in a basin on the eroded crest of an anticline." The eastern limb of this anticline has been intruded by a batholith of granite, which forms the "backbone of the St. John's Peninsula." The block that contains the Cambrian and Ordovician rocks has been dropped a distance which Professor vanIngen has estimated at 8,000 feet along a great fault that is well exposed at Topsail Head, 3 miles northeast of Manuels (Buddington, 1916, p. 131; 1919, pp. 455, 475).

The whole surface of the Peninsula of Avalon has been deeply carved by the Pleistocene ice. Great quantities of drift are scattered over the surface of the land; and there are lakes and ponds of glacial origin everywhere. Dr. Buddington (1919, pp. 452, 453) states that the striae on the rocks indicate that there were "local ice caps flowing into the individual bays in a direction perpendicular to the major outlines of the bays at each point," and that each of the bays "presents all the essential characteristics of a fiord." All of the large, and most of the small, bays and harbors lie with their long axes parallel to the N.NE.-S.SW. major structural axes of the region.

IV. GENERAL DESCRIPTION OF THE WHOLE CAMBRIAN SECTION AT MANUELS

The general character and distribution of the early Paleozoic beds at Manuels are indicated on the horizontal section and the outcrop map exhibited in figures 2d and 3 (p. 16). A glance at the map will show that most of the exposures are in the valley of Manuels Brook, the outcrops of the basal conglomerate being at the falls and those of the higher beds following in succession down the stream from that point toward the shore of the bay. Scattered outcrops occur, however, outside of the brook valley, especially along the wagon roads and the railway. The strike of the beds between the bottom of the basal conglomerate and the top of the highest Paradoxides zone is about N. 82° E., true meridian, and the dip is approximately 10° to the north. These or similar figures will probably be found to apply to the rest of the beds of the section when those beds are carefully studied. No faults or thrusts of any importance have been detected anywhere in the section, but some of the shales show many slickensided surfaces, as though they had slumped toward the north by a series of small movements among themselves.

The basal beds of the Lower Cambrian, varying considerably in character (and perhaps in age) even in the small area included in the map (Fig. 3), are conglomerates in and adjacent to the brook valley, and limestones and shales at and southwest of the railway station platform. They appear to be deposits that accumulated along an uneven rocky shore. At the falls of the brook the conglomerate is 18 feet thick, and consists of well rounded boulders and pebbles, apparently derived from the adjacent Pre-Cambrian, with the interstices between them filled with sand. It is coarsest at its base, where some of its boulders are said to measure as much as 12 feet in diameter (Dale, 1915, p. 377), and grades upward through 3 feet of limy

FIGURE 3. Map showing the location of Exposures of Cambrian beds at Mammals



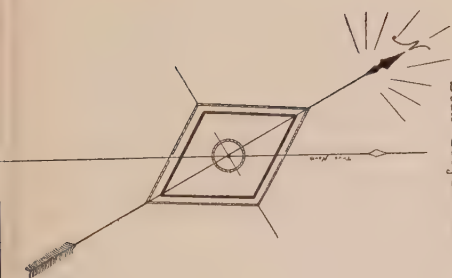


CAMBRIAN OUTCROPS

A T

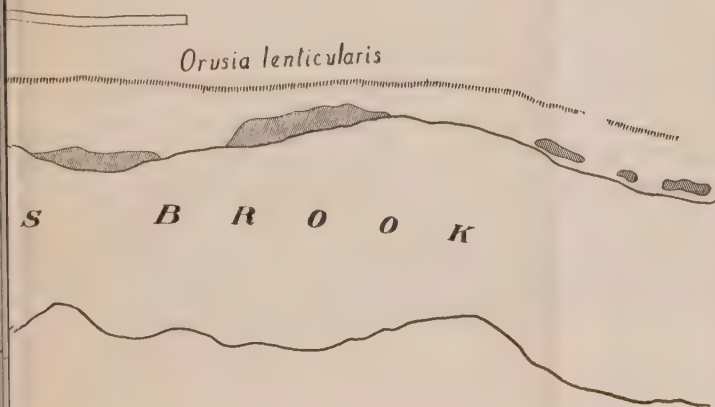
MANUELS

100' 200' 300' 400'
Scale 300 feet = 1 inch



Orusia lenticularis

S B R O O K



sandstone into a shaly, pyritiferous, pink and blue limestone containing great numbers of what are probably pteropod shells.

The beds next above this limestone in the brook section are almost entirely concealed, but a single small exposure in the bed of the stream, and many loose pieces in the soil of the adjacent fields, indicate that they are probably hard olive gray shales. The next higher bed is exposed a little farther down the stream. It is a red shale, $2\frac{1}{2}$ feet thick, which merges upward through some 6 inches of red and green limy shale into a bed described by Dr. Dale (1915, p. 380) as a "nodular and pebbly reddish blue limestone," which is $1\frac{1}{2}$ feet thick, and contains many fragmentary fossils. Overlying this, and exposed both in the banks of the stream and along the near-by wagon roads, are about 34 feet of hard, olive gray shale, which breaks with a conchoidal fracture and contains occasional black nodules, up to 1 inch in diameter, some of which, according to Dr. Dale (1915, p. 385), "show pinkish centers of some fine-grained minerals such as rhodocrosite or manganiferous calcite." Dr. Dale has stated that the contact of this shale and the underlying limestone, as exposed in the bank of the stream, is a disconformable one. It is certainly a very uneven one; but the beds seem sometimes to grade into each other. A very careful and detailed study and comparison of this limestone and shale and the similar limestones and shales that outcrop in the vicinity of the railway will have to be made before their relative ages and the character of their contacts will be fully understood. This 34-foot thick olive-gray shale shows many small slicken-sided surfaces, and at most places yields very few fossils. In the brook exposures it has yielded nothing but some small brachiopods, and in the outcrops along the wagon roads it appears to be quite barren. In a railway cut just southwest of the railway station platform, however, beds almost certainly referable to some part of it contain a small fauna. One of the members

of this fauna, a large trilobite named *Catadoxides magnificus*, is believed by Dr. Matthew, who discovered it, to be closely related to the Sardinian genus, *Metadoxides* (Matthew, 1899b; 1899c, pp. 83-87, pl. VIII).

The succeeding beds of the section are well exposed only in the valley of the brook. The first one is a peculiar, dark bluish gray shale, 4 to 5 inches thick, and full of flattened, subspherical nodules, which are 1 inch or less in diameter and are probably composed, according to Dr. Dale (1915, p. 385), of manganiferous calcite. On top of this nodular bed is a thin layer of what Dr. Dale (1915, p. 385) has described as a "Cryptozoon shale," containing "roughly concentric or zonal structures measuring $1\frac{1}{2}$ inches in diameter, irregular and subspherical nodules measuring 1 inch in diameter, and intercalated lenses of manganiferous calcite." Above this "Cryptozoon" layer is a three-foot bed of hard, green shale, with manganiferous calcite nodules in its upper portion, and near its base specimens of a trilobite apparently specifically identical with Dr. Matthew's "*Catadoxides magnificus*."* This fossiliferous bed is followed by 10 feet and 10 inches of unfossiliferous, manganiferous, red and green shales, some of which contain small, flattened nodules. Most of these nodules are similar to those occurring in the beds below, but some of them may be phosphatic.

The next higher stratum is possibly the lowest of the *Paradoxides* beds in this section. It and the beds which succeed it, up to the top of the highest one known to contain

* These specimens were tentatively identified by Professor vanIngen in 1915 as "*Protolenus harveyi*" (Dale, 1915, p. 390), a species which Dr. Walcott had described as "*Solenopleura harveyi*" (Walcott, 1890, p. 45; 1891a, p. 656, pl. 97, figs. 8, 8a, not figs. 7, 7a). A recent examination of examples of Dr. Matthew's "*Catadoxides magnificus*" from the type locality of that species (the railway cut just southwest of the railway station platform at Manuels) has convinced Professor vanIngen that his own specimens are more like that form than like Dr. Walcott's figure of "*Solenopleura harveyi*." Dr. Walcott's and Dr. Matthew's species are, however, very similar, and may be identical, their ostensible differences being perhaps due to differences in the size and preservation of the specimens on which they are based.

Paradoxides, consist of 302 feet of shales, containing occasional nodules, lenses, and thin beds of limestone. The lower 234 feet, which are grayish, heavy-bedded, hard shales, holding few fossils except in their upper 13 feet, grade gradually upward, through brown and finer-bedded shales with abundant fossils, into thin-bedded, soft, black shales, filled with trilobites. As all these beds will be discussed in detail in the next chapter, no further description of them will be given here.

The beds that overlie the uppermost known Paradoxides beds are thin-bedded, often papyraceous, dark gray and black shales, with frequent nodules of pyrite. They and their fossils have not been carefully studied. Near their base they appear to be barren. Some thirty feet up from the bottom, however, a few fossils have been found, including a brachiopod, an agnostid trilobite, and a small bivalved crustacean, which may indicate the presence of the "*Paradoxides forchhammeri*" and "*Agnostus lævigatus*" zones, the two uppermost known divisions of the Paradoxides beds, which are well developed in Scandinavia. These beds of doubtful age are succeeded by finely-bedded black shales containing a trilobite resembling *Agnostus pisiformis* (Linné), which are followed by similar shales holding *Agnostus pisiformis obesus* Belt, and other types characteristic of the "Olenus beds" of northwestern Europe. Above these "*pisiformis obesus*" beds are micaceous shales and sandstones showing ripple marks and other evidences of a shallow-water origin. These micaceous shallow-water beds, which include the highest beds of the brook section, seem to be barren, for the most part; but a few species, the majority of them brachiopods, have been found, one of which, *Orusia lenticularis* (Wahlenberg), is abundant at some horizons. No detailed measurements have been made of any of these beds above the Paradoxides zones. Their total thickness is probably some 400 or 500 feet.

V. DETAILED DESCRIPTION OF THE PARADOXIDES BEDS EXPOSED IN THE VALLEY OF MANUELS BROOK

Stratigraphical and Faunal Succession

The first published description of the Paradoxides beds at Manuels is contained in Murray's report of the progress of the Newfoundland Geological Survey for 1868, where, after describing the conglomerate which forms the bottom of the Cambrian section in the brook valley, he mentions the other beds exposed along the stream as follows: "About 400 yards below the bridge the conglomerate is overlaid conformably by a set of dark brown or blackish shales, with a very fine lamination coinciding with the bedding, which, with some hard calcareous beds interstratified, hold the banks of the brook until within a short distance of its exit into the bay." (Murray and Howley, 1881a, p. 154.)

Fossils were first discovered in the beds in (Weston, 1898, p. 153). They were collected by T. C. Weston, of the Canadian Geological Survey, and were examined by J. F. Whiteaves, paleontologist of that survey, who recognized the following eight species: "Agnostus Acadicus Hartt," "Agnostus (sp. undet.)," "Microdiscus punctatus Salter," "Microdiscus Dawsoni Hartt," "Conocephalites tener Hartt," "Conocephalites Baileyi Hartt," "Conocephalites Orestes ? Hartt," and "Paradoxides (sp. undet.)." (Whiteaves, 1878.)

In 1887 Dr. Matthew added four more species: "Paradoxides sp.," "Agnostus gibbus (?) Linrs," "Agrauios socialis, Bill," and "Hyolithes, Sp." (Matthew, 1887, p. 149).

In 1889 Dr. Walcott published a description of the section at Manuels, a part of which is quoted herewith (Walcott, 1889a, pp. 380, 381):

6. Green argillaceous shale with thin layers of hard, dark, ferruginous sandstone, interbedded at several horizons----- 270
Strike, N.80°E; Dip 12° N.

Fossils—Near the base the head of an *Olenellus* was found, also fragments of an *Agraulos* or *Ptychoparia*. At 218 feet from the base a layer of pinkish limestone contained the head of an *Agraulos*, like *A. strenuus*, and many fragments of trilobites. Fifty-two feet higher up quite an abundant fauna was found, and the following species were collected: *Lingulella*, sp. a, *Acrothele Matthewi* Hartt (sp.), *Agnostus* sp. a, *Agnostus* sp. d, *Paradoxides Hicksi* Salter, *Conocoryphe Matthewi* Hartt (sp.), *Liostracus* sp. a.

7. Dark argillaceous shales with thin layers of limestone and sandstone, at various horizons----- 295

Fossils—Zone a. From 10 to 20 feet from the base the following species were collected: *Lingulella* sp. a, *Linnarssonina misera* Billings, *Acrothele Matthewi* Hartt (sp.), *Hyo-lithes* sp. a, *Agnostus*, 3 sp., a, b, c, *Microdiscus punctatus* Salter, *Paradoxides Hicksi*, *Conocoryphe* (C) *Matthewi* Hartt (sp.), *Conocoryphe elegans* Hartt (sp.), *Agraulos socialis* Billings, *Liostracus tener* Hartt (sp.).

Zone b. Forty-five feet higher up the fauna is much larger and includes: *Linnarssonina misera* Billings (sp.), *Lingulella* sp. a, *Orthis* sp. ?, *Stenothea* sp. ?, *Agnostus punctuosus* Angelin, *Agnostus* 5 sp., b, e, f, g, h, *Microdiscus punctatus* Salter, *Paradoxides Davidis* Salter, *Paradoxides Hicksi* Salter, *Paradoxides* sp. ?, *Anopolenus venustus* Billings, *Conocoryphe elegans*, *Ctenocephalus Matthewi* Hartt (sp.), *Errinnys venulosa* Salter, *Ptychoparia Robbi* Hartt, *P. variolaris* Salter, *Holocephalina inflata* Hicks, *Agraulos socialis* Billings. From 235 to 250 feet from the base a belt occurs in which a small species of *Aristozoa* occurs in large numbers, associated with *Lingulella* sp. a, *Agnostus* sp. ? and the heads of a small *Ptychoparia* ?, sp. undet.

All of Dr. Walcott's division "6", except the lower part, and all of zones "a" and "b" of his division "7" are *Paradoxides* beds. "*Ptychoparia Robbi* Hartt" of zone "b" of division "7" is the only species mentioned by Dr. Walcott that the writer has not recognized as such in the material from Manuels that he has studied; it may be identical with the trilobite referred to as "*Solenopleura* cf. *applanata* (Salter)" in the faunal lists of the present chapter (see p. 37).

Dr. Walcott later described from the *Paradoxides* beds at this locality the brachiopod, *Acrothele prima costata*

(Matthew), a new brachiopod, *Obolus fragilis*, and a new trilobite, "Karlia" minor (which he subsequently referred to the genus *Corynexochus*), and a new brachiopod, "*Plectorthis papias*" (which he afterward placed in the genus *Eoorthis*). This writer has found three of these species in his Manuels collections, but has not recognized any examples of the other, the *Acrothele*.

In 1896 Dr. Matthew recorded from the "sub-zone of *P. Davidis*" at Manuels three species, "*Plumulites Manuelensis*, n. sp.," "*Agnostus Davidis*, Hicks," and "*Microdiscus punctatus*, Salter" (Matthew, 1896, pp. 200, 225, 226, 244, 245). He was doubtful about his identification of *Agnostus davidis*, as it was based on a single pygidium. The writer has found no examples of *davidis* in the Princeton collections from Manuels. Perhaps the pygidium described by Dr. Matthew belongs to the large agnostid which is referred to in the present paper as "*Agnostus lævigatus ciceroideus* Matthew." The writer has not yet identified any specimens of Dr. Matthew's "*Plumulites Manuelensis*" in his material from Manuels.

In his "*Lethæa geognostica*" Frech stated that "*Conocephalus (Liostracus) Linnarssoni Brögg.*" occurred in Dr. Walcott's zone 7b at Manuels (Frech, 1897, p. 38); but this must have been a mistake on his part, for Dr. Walcott did not record it from there, and Frech gave no other authority for his record. The writer has not found the species in his collections.

In 1899 Dr. Matthew recorded "*Erinnys breviceps*, Ang." from beds containing the "*Paradoxides Davidis* sub-fauna" at Manuels, and "*Atops trilineatus*, Emmons" from "a greenish gray fine shale, similar to that which at that locality . . . holds fossils of the *P. Davidis* subzone of the *Paradoxides* Beds, where probably it belongs." Matthew, 1899c, pp. 89-95.) The writer has not found at Manuels any specimens that seem to him to be referable to *Erinnys breviceps*, although a form which he has identified as

Salter's "*Erinnys venulosa*" (called "*Bailiella venulosa*" in the present paper) is not uncommon in some of the beds there. It is therefore perhaps possible that Dr. Matthew's specimen is a *venulosa*, rather than a *breviceps*. No specimen of *Atops trilineatus*, except the one described by Dr. Matthew, has ever been recorded from Newfoundland, and, as this species has not been discovered during the careful collecting that has been done in the Paradoxides beds at Manuels, and occurs in beds supposed to be of pre-Paradoxidian age in New York, it seems probable that Dr. Matthew's Manuels example came from one of the greenish gray shales which occur beneath the lowest known Paradoxides beds, and not from the much higher horizon that Dr. Matthew supposed.

The only other species which have been recorded from the Paradoxides beds of Newfoundland that the writer has not identified at Manuels are *Micromitra* (*Iphidella*) *pannula maladensis* (Walcott), listed by Dr. Walcott from a "limestone near the base of the Middle Cambrian, the lowest horizon carrying Paradoxides, northwest side of Chapple Arm Harbor, about 1 mile (1.6 km.) from its head, Trinity Bay" (Walcott, 1912, p. 169), "*Bathyrurus gregarius*, described by Billings from Trinity Bay (Billings, 1865, p. 363), "*Eocystites*, sp.," "*Agnostus lævigatus*, Dalm.," and *Agnostus fissus trifissus* Matthew, from the "Davidis Subzone at Chapel Arm, Trinity Bay" (Matthew, 1887, p. 150; 1896, p. 231), and "*Centropleura Loveni*, Ang.?", "*Agnostus brevifrons*, Ang.," and "*Agnostus lævigatus*, Dalm.," from Highland Cove in Trinity Bay (Matthew, 1887, p. 150). Billings described what he believed to be two new species of Paradoxides (*P. tenellus* and *P. decorus*) from "Chapel Arm" in 1872 (Billings, 1874, pp. 74, 75); but an examination of specimens of trilobites in the museum at St. John's, Newfoundland, that are labeled "*Paradoxides decorus*" and "*Paradoxides terrelus*" and are supposed to be Billings' types, has convinced the writer that both these species are

synonyms of *Paradoxides hicksi* Salter—"decorus" being based on adult specimens and "tenellus" on young ones. Professor Raymond suggested some years ago that "tenellus" might prove to be the young of "decorus" (Raymond, 1914, p. 234).

In 1900 Dr. Walcott published some notes on the Cambrian stratigraphy at Manuels, in which he described the strata which he thought marked the upper and lower limits of the "Middle Cambrian" and of the "great *Paradoxides* zone" there (Walcott, 1900, pp. 315-317). The stratum which he described as the bottom bed of the "Middle Cambrian" is the "nodular and pebbly reddish blue limestone" referred to on page 25 of the present paper. The stratum designated by him as the basal bed of the "great *Paradoxides* zone," the lowest horizon at which he found *Paradoxides*, is bed 19 of the present chapter (see p. 54). His description of the bed which he believed to mark the top of the "Middle Cambrian" is quoted and discussed on page 29 of this paper.

In a footnote on pages 315 and 316 of his 1900 paper Dr. Walcott stated that the "head of an *Olenellus* and fragments of *Agraulos* or *Ptychoparia*" that had been recorded by him in 1889 from near the base of his division '6' (see quotation on page 29 of the present paper), had probably actually come from a lower horizon, beneath the "conglomerate limestone" which underlies his division "6."

The only beds of the Manuels Brook Cambrian section that can be stated with certainty, or with any considerable degree of probability, to be of *Paradoxidian* age consist of 302 feet of shales and thin limestones. They are overlain by black shales that have yielded no satisfactory index fossils and whose age is therefore unknown. They are underlain by 10 feet and 10 inches of unfossiliferous manganiiferous shales of undetermined age, as described on page 26. All of their 302 feet, except the lowest 3, can definitely be proved to have been formed during *Paradoxian*



FIG. 1. View down the gorge of Manuel's Brook, showing exposures of beds of the *Paradoxides bennetti* zone (beds 1-20) and the underlying manganiferous beds.



FIG. 2. View of beds 1-15 and the underlying manganiferous beds, as they are exposed in the left wall of the gorge of Manuel's Brook. The cliff here pictured is the one shown in the extreme lower left corner of figure 1.

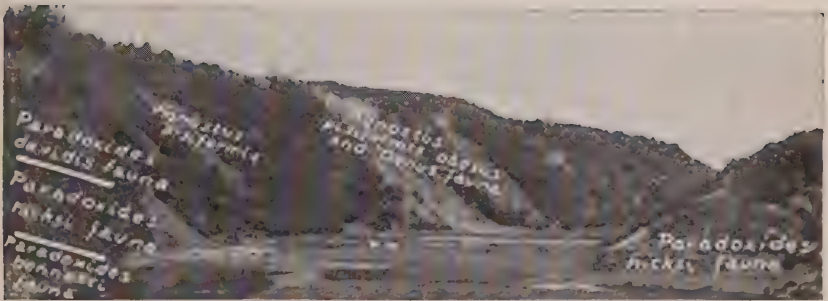


FIG. 1. View down the gorge of Manuels Brook, down the stream from the part of the gorge shown in plate 1, figure 1, showing exposures of beds of the *Paradoxides bennettii* zone, the *P. hicksi* zone, and the *P. davidis* zone, and the shales containing *Agnostus pisiformis* and *A. pisiformis obesus* and *Olenus*.



FIG. 2. View of beds of the *Paradoxides bennettii* zone (beds 20-35), the *P. hicksi* zone (beds 36-92), the *P. davidis* zone (beds 93-125), and some of the overlying beds of undetermined age, as they are exposed in the left wall of the gorge of Manuels Brook. The exposures here pictured are those shown at the extreme left side of figure 1.

time. The fossils that have been found in this basal 3 feet are so fragmentary that they can not be identified, but they appear to be most probably referable to a Paradoxides fauna, and a description of the beds is therefore included in the present chapter. The 10 feet of manganiferous shales beneath these beds, and the black shales overlying the highest known Paradoxides horizon, may also be of Paradoxidian age; but they appear to show no evidence of being so, and therefore will not be considered in the present chapter, where only the 299 feet that were surely, and the underlying 3 feet that were probably, formed during Paradoxidian time will be discussed. A section and table, showing the stratigraphical and faunal succession of the known Paradoxides beds that are exposed in the valley of the brook, are exhibited in figure 2d and Table IV (pp. 16 and 56), and the outcrops and exact positions of the various beds and faunal horizons are indicated in the figures on plates 1 and 2. No exposure showing a continuous section of these beds is to be found on either side of the brook valley; but a practically complete composite section can be obtained by combining the parts outcropping on the two sides. The section shown in figure 2d (p. 16) and described in the present chapter, was gotten in this way. Some mistakes may have been made in joining up the parts of this section that were exposed in unconnected outcrops, but it is believed that none of these errors can have been large or important. The lithological characters and the faunas of the individual beds are described in detail in the succeeding pages of this chapter, and are discussed on pages 57 to 72. Beds 21 to 125 are described as they occur on the western side of the brook valley. They appear to be of essentially the same character in the exposures on the eastern side.

The growth of our knowledge of the relationships existing between the Paradoxides faunas of Newfoundland and those of northwestern Europe and northeastern North America will probably necessitate the changing of a number of the specific and varietal names used in this paper,

for the writer has attempted to identify his specimens from Manuels with previously described American and European species and varieties without entering into any discussion of the exact relationships or possible equivalences of those previously described forms. Detailed comparisons of the European and American forms will be included in a monograph on the Paradoxides faunas of southeastern Newfoundland, which is now in preparation. The new species and varieties mentioned in the faunal lists of the present paper are described farther on.

All the species of agnostid trilobites in these faunal lists are placed in the single "genus," *Agnostus*. The writer believes, with Corda (Hall and Corda, 1847), Tullberg (1880, pp. 11-15), Jækel (1909), and Raymond (1913, pp. 2 and 3), that these species should be referred to more than one genus; but, as he has been unable to assign some of them to the genera of any classification of the group that has yet been proposed, he has followed the old practice of grouping them all in "*Agnostus*." This procedure has at least the advantage of making the names of many of the species more intelligible to the majority of his readers than the names would have been had he referred the species to what are really their proper genera; for to the minds of most paleontologists "*Agnostus*" undoubtedly conveys more meaning than do "*Condylomyia*," "*Pleuroctenium*," "*Lejopyge*," "*Peronopsis*," or "*Phalacroma*." The best generic classification of the agnostids that has yet been proposed is that advocated by Professor Raymond (Raymond, 1913). The writer believes that, in most respects, that classification is satisfactory as far as it goes, but that it is not complete; and Dr. C. E. Resser and he are now making a detailed study of all the agnostids, in the hope of obtaining a fuller knowledge of the true lines of descent and the proper classification of that very interesting group of little trilobites.

STRATIGRAPHICAL AND FAUNAL SUCCESSION OF THE PARADOXIDES BEDS EXPOSED IN THE VALLEY OF MANUELS BROOK

The letters in parentheses indicate the relative abundance or rarity of the species, thus: r—rare, c—common, a—abundant, va—very abundant.

The ° and / mark the earliest and latest known occurrences of the species in the section, thus: °—earliest known occurrence; /—latest known occurrence.

BED NO.	LITHOLOGICAL CHARACTER	THICKNESS FEET. INCHES.
125.	Dark gray slightly micaceous, phosphatic, carbonaceous shale, containing so many small lumps of black, carbonaceous, phosphatic material that it looks almost like a conglomerate. These lumps, which appear to be either pebbles or concretions, vary from a small fraction of an inch to 3 inches in diameter, and often contain fossils. The top and bottom of the bed are uneven, but appear to show no clear evidence of the beds having been eroded after its consolidation.	0 2
	Paradoxides sp. undet. (probably <i>P. davidis</i> Salter) (r)	
	Hyalolithid gen. and sp. undet. (possibly <i>Hyalolithes tenuistriatus</i> Linnarsson) (r).	
	This is the highest known Paradoxides bed in the section, the top of the "Paradoxides davidis zone" of this paper (see p. 59).	
124.	Hard greenish gray shale. The top is uneven against the uneven bottom of bed 125 and the change in lithological character between the two beds is abrupt, but there does not appear to be any clear evidence of a sedimentary break or of the erosion of bed 124 after its consolidation.	0 1
	Paradoxides sp. undet. (probably <i>P. davidis</i> Salter) (r).	
123.	Grayish white clay-like material, apparently resulting from the weathering of a gray shale, small pieces of which occur in the "clay".	0 1
	No fossils found.	
122.	Hard, heavy-bedded dark greenish gray and blackish shales, containing numerous black, carbonaceous, phosphatic "pebbles," 1 inch or less in diameter, similar to those in bed 125.	0 5
	/Paradoxides davidis Salter (c).	
121.	Pyritiferous black shale.	2 2
	Paradoxides davidis Salter (r).	

120. Pyritiferous black shale-----	1	2
<i>Paradoxides davidis</i> Salter (r).		
/ <i>Agnostus punctuosus</i> Angelin (r).		
/ <i>Agnostus lævigatus ciceroide</i> s Matthew (r).		
119. Black shale containing a few limestone nodules, some of which are a foot or more in diameter, and many small nodules of pyrite and lumps or pebbles of phos- phatic material -----	0	8
<i>Paradoxides davidis</i> Salter (va).		
/ <i>Corynexochus</i> cf. <i>minor</i> (Walcott) (r).		
<i>Agnostus punctuosus</i> Angelin (c).		
<i>Agnostus lævigatus ciceroide</i> s Matthew (r).		
<i>Brachiopod</i> gen. and sp. undet. (r).		
118. Soft pyritiferous bluish black shale, intermediate in character between 119 and 117-----	0	4
<i>Paradoxides davidis</i> Salter (r).		
<i>Agnostus punctuosus</i> Angelin (r).		
<i>Agnostus lævigatus ciceroide</i> s Matthew (r).		
117. Soft, thin-bedded, dark gray shale containing many small concretions of pyrite-----	0	7
<i>Paradoxides davidis</i> Salter (a).		
<i>Centroleura</i> sp. undet. (r).		
<i>Agnostus punctuosus</i> Angelin (r).		
<i>Agnostus lævigatus ciceroide</i> s Matthew (c).		
/ <i>°Agnostus</i> cf. <i>incertus</i> Brögger (r).		
116. Pyritiferous dark gray shale-----	0	9
<i>Paradoxides davidis</i> Salter (a).		
/ <i>Paradoxides rugulosus</i> Corda (r).		
<i>Corynexochus</i> cf. <i>minor</i> (Walcott) (r).		
<i>Conocoryphe</i> sp. undet. (r).		
<i>Agnostus punctuosus</i> Angelin (r).		
<i>Agnostus lævigatus ciceroide</i> s Matthew (c).		
/ <i>°Agnostus</i> cf. <i>fallax</i> Linnarsson (r).		
/ <i>°Protospongia fenestrata</i> Salter (r).		
115. Pyritiferous dark gray shales, slightly harder and heavier-bedded than 116, containing occasional flat limestone nodules, 1 inch to 6 inches thick, some of which hold fossils. A 2-inch bed of shale, full of small phosphatic "pebbles" like those in bed 125, occurs 2 feet above the base-----	2	8
<i>Paradoxides davidis</i> Salter (va).		
° <i>Paradoxides rugulosus</i> Corda (r).		
/ <i>°Centroleura henrici</i> (Salter) (r).		
/ <i>°Solenopleura variolaris</i> (Salter) (r).		
/ <i>°Solenopleura communis</i> Billings (r).		
/ <i>°Holocephalina primordialis</i> Salter (c).		
/ <i>Eodiscus punctatus</i> Salter (r).		
<i>Agnostus punctuosus</i> Angelin (r).		
<i>Agnostus lævigatus ciceroide</i> s Matthew (c).		
/ <i>Agnostus lævigatus terranovicus</i> Matthew (c).		

- /° *Agnostus lævigatus* mamilla Matthew (r).
Agnostus cf. fallax Linnarsson (r).
 /*Agnostus* cf. acadicus declivis Matthew (r).
 /*Obolus fragilis* (Walcott) (r).
 /° *Stenothecha* cf. cornucopia Salter (r).
 /° *Hyalithes* cf. tenuistriatus Linnarsson (r).
114. Hard, heavy-bedded, dark gray limy shale, some parts of which, more limy than the rest, are full of fragments of *Paradoxides davidis*----- 1 0
Paradoxides davidis Salter (va).
Centroleura sp. undet. (r).
Agnostus lævigatus terranovicus Matthew (r).
Agnostus cf. fallax Linnarsson (r).
113. Hard, dark gray shale with flat nodules of limestone in its upper part----- 0 6
Centroleura sp. undet. (r).
 /*Bailiella venulosa* (Salter) (r).
 /*Hartshillia inflata* (Hicks) (r).
Agnostus lævigatus ciceroideus Matthew (c).
Agnostus cf. acadicus declivis Matthew (c).
Brachiopod gen. and sp. undet. (r).
112. Hard black and dark gray shales, some layers of which are covered with fragments of trilobites----- 0 7
Centroleura sp. undet. (r).
Hartshillia inflata (Hicks) (c).
 /*Solenopleura* cf. applanata (Salter) (c).
Eodiscus punctatus (Salter) (r).
Agnostus lævigatus terranovicus Matthew (c).
Agnostus cf. fallax Linnarsson (r).
 /*Agnostus rex* (Barande) (r).
Hyalithid gen. and sp. undet. (r).
111. Pyritiferous black and gray shales, not quite so hard as 112 ----- 0 10
Paradoxides davidis Salter (r).
Solenopleura cf. applanata (Salter) (r).
 ° *Hartshillia inflata* (Hicks) (r).
Agnostus punctuosus Angelin (va).
Agnostus lævigatus terranovicus Matthew (a).
Agnostus cf. fallax Linnarsson (c).
110. Pyritiferous black shale with occasional thin gray bands. Not quite so hard as 111----- 1 3
Paradoxides sp. undet. (r).
Solenopleura cf. applanata (Salter) (r).
Agnostus punctuosus Angelin (va).
Agnostus lævigatus ciceroideus Matthew (r).
Agnostus lævigatus terranovicus Matthew (a).
Agnostus cf. fallax Linnarsson (c).
 /*Agnostus* cf. nudus (Beyrich) (r).
 /*Agnostus* cf. granulatus (Barrande) (r).
 /*Agnostus sulcatus* Illing (r).

- /° *Agnostus* cf. *pusillus* Tullberg (r).
 Hyolithid gen. and sp. undet. (r).
109. Pyritiferous brown-weathering gray and black shales,
 in alternating thin beds. Slightly softer than 116.
 Contains occasional small nodules of pyrite, and a
 great many fossils----- 0 10
- Paradoxides* sp. undet. (r).
Bailiella *venulosa* (Salter) (r).
Solenopleura cf. *applanata* (Salter) (a).
 ° *Corynexochus* *minor* (Walcott) (r).
Eodiscus *punctatus* (Salter) (va).
Agnostus *granulatus* (Barrande) (r).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus *sulcatus* Illing (r).
 /° *Agnostus* *longifrons* *parvulus* n. var. (r).
 /° *Agnostus* cf. *exaratus* *tenuis* Illing (c).
Agnostus *punctuosus* Angelin (r).
Agnostus *laevigatus* *ciceroides* Matthew (r).
Agnostus *laevigatus* *terranovicus* Matthew (a).
Agnostus cf. *fallax* Linnarsson (a).
Agnostus cf. *academicus* *declivis* Matthew (r).
Agnostus *rex* (Barrande) (r).
 /° *Agnostus* *gracilis* Illing (r).
 /° *Agnostus* cf. *kjerulfi* Brögger (r).
 ° *Obolus* *fragilis* (Walcott) (r).
 /° *Acrotreta* *misera* (Billings) (r).
 Hyolithid gen. and sp. undet. (r).
108. Soft slightly pyritiferous black shale----- 1 1
- Centropheura* sp. undet. (r).
Solenopleura cf. *applanata* (Salter) (r).
Eodiscus *punctatus* (Salter) (a).
Agnostus *punctuosus* Angelin (a).
Agnostus *laevigatus* *terranovicus* Matthew (a).
Agnostus cf. *fallax* Linnarsson (a).
Agnostus *granulatus* (Barrande) (c).
Acrotreta *misera* (Billings) (r).
107. Soft pyritiferous black shale----- 1 0
- Solenopleura* cf. *applanata* (Salter) (r).
Eodiscus *punctatus* (Salter) (r).
Agnostus *punctuosus* Angelin (a).
Agnostus *laevigatus* *terranovicus* Matthew (a).
Agnostus cf. *academicus* *declivis* Matthew (r).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus *granulatus* (Barrande) (c).
Agnostus cf. *kjerulfi* Brögger (r).
 /° *Agnostus* cf. *parvifrons* *mammillatus* Brögger (r).
 /° *Agnostus* *bibullatus* (Barrande) (r).
Acrotreta *misera* (Billings) (r).
106. Soft pyritiferous black shale----- 1 10
- Paradoxides* sp. undet. (r).

Eodiscus punctatus (Salter) (c).
Agnostus punctuosus Angelin (c).
Agnostus lævigatus terranovicus Matthew (va).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus granulatus (Barrande) (c).
 °*Agnostus bibullatus* (Barrande) (r).
Acrotreta misera (Billings) (c).
Hyolithid gen. and sp. undet. (r).

105. Soft black shale with some very thin brownish layers... 0 7
Solenopleura cf. *applanata* (Salter) (r).
Eodiscus punctatus (Salter) (c).
Agnostus punctuosus Angelin (r).
Agnostus lævigatus terranovicus Matthew (c).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus granulatus (Barrande) (r).
Agnostus cf. *kjerulfi* Brögger (r).
 °*Agnostus* cf. *parvifrons* *mammillatus* Brögger (r).
Acrotreta misera (Billings) (c).
104. Thin-bedded soft gray and black shales..... 0 8
Agnostus lævigatus terranovicus Matthew (r).
Agnostus cf. *fallax* Linnarsson (r).
Acrotreta misera (Billings) (r).
103. Thin-bedded pyritiferous soft black and gray shales... 1 0
Eodiscus punctatus (Salter) (c).
Agnostus lævigatus terranovicus Matthew (c).
Agnostus sulcatus Illing (r).
Acrotreta misera (Billings) (c).
102. Thin-bedded pyritiferous soft black shale with a few thin gray and brown layers. In its upper 5 inches it is much like bed 103. Contains occasional small nodules of pyrite..... 1 4
Paradoxides sp. undet. (r).
Solenopleura cf. *applanata* (Salter) (r).
Eodiscus punctatus (Salter) (va).
Agnostus lævigatus ciceroideus Matthew (c).
Agnostus lævigatus terranovicus Matthew (va).
Agnostus cf. *fallax* Linnarsson (a).
Agnostus granulatus (Barrande) (r).
Agnostus sulcatus Illing (r).
 °*Agnostus* cf. *gracilis* Illing (r).
Agnostus cf. *kjerulfi* Brögger (r).
 /*Agnostus vaningeni* n. sp. (r).
Acrotreta misera (Billings) (r).
101. Thin-bedded pyritiferous soft black shale with a few thin gray layers..... 1 6
Paradoxides sp. undet. (possibly *P. davidis* Salter) (r).
 /*Paradoxides* cf. *hicksi* Salter (r).
Eodiscus punctatus (Salter) (a).

- Agnostus* cf. *fallax* Linnarsson (a).
Agnostus cf. *nudus* (Beyrich) (c).
Agnostus *granulatus* (Barrande) (r).
Agnostus *sulcatus* Illing (r).
Agnostus cf. *kjerulfi* Brögger (r).
[°]*Agnostus* *parvifrons punctifer* n. var. (r).
Acrotreta *misera* (Billings) (r).
Lingulella *ferruginea* Salter (r).
100. Thin-bedded pyritiferous soft black shale----- 1 6
Paradoxides sp. undet. (possibly *P. davidis* Salter) (r).
Agnostus *laevigatus terranovicus* Matthew (r).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus *granulatus* (Barrande) (r).
Agnostus *sulcatus* Illing (r).
Agnostus cf. *kjerulfi* Brögger (r).
Agnostus *vaningeni* n. sp. (r).
Acrotreta *misera* (Billings) (r).
Stenothea sp. undet. (r).
99. Thin-bedded pyritiferous soft black shale----- 0 8
[°]*Centropleura* *pugnax* Illing (r).
Solenopleura cf. *applanata* (Salter) (r).
Eodiscus *punctatus* (Salter) (r).
Agnostus *punctuosus* Angelin (c).
Agnostus *laevigatus ciceroides* Matthew (r).
Agnostus *laevigatus terranovicus* Matthew (r).
Agnostus cf. *fallax* Linnarsson (va).
Agnostus cf. *acadicus declivis* Matthew (r).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus *granulatus* (Barrande) (r).
[°]*Agnostus* cf. *kjerulfi* Brögger (r).
Agnostus *sulcatus* Illing (c).
[°]*Agnostus* cf. *parvifrons* Linnarsson (r).
Agnostus cf. *exaratus tenuis* Illing (r).
[°]*Agnostus* cf. *fissus perrugatus* Grönwall (va).
[°]*Agnostus* *vaningeni* n. sp. (r).
Acrotreta *misera* (Billings) (c).
Hyalolithid gen. and sp. undet. (r).
Stenothea sp. undet. (r).
98. Soft, but compact, black shale, in layers 1/4 to 1/3 of an inch thick----- 0 4
 No fossils found.
 The absence of fossils from this black shale is remarkable, as the very similar black shales above and below it are richly fossiliferous.
97. Soft pyritiferous black shale with occasional flat lenses of limestone. Contains several beds of white clay-like material, 1/16 of an inch thick, and has a similar bed, 1/2 of an inch thick, at the top----- 1 3

- Agnostus punctuosus* Angelin (r).
Agnostus cf. *fallax* Linnarsson (r).
Agnostus sulcatus Illing (r).
96. Soft pyritiferous black shale, similar to bed 95, but with *Agnostus punctuosus* much the most abundant member of the fauna----- 0 8
Paradoxides davidis Salter (c).
Agnostus punctuosus Angelin (va).
Agnostus cf. *fallax* Linnarsson (r).
Agnostus sulcatus Illing (r).
95. Soft pyritiferous black shale----- 1 0
Paradoxides davidis Salter (c).
°*Agnostus punctuosus* Angelin (c).
Agnostus cf. *fallax* Linnarsson (a).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus granulatus (Barrande) (c).
Agnostus sulcatus Illing (a).
Hyalolithid gen. and sp. undet. (r).
94. Very soft pyritiferous black shale, similar to 95, but softer and less fossiliferous. Breaks into little hexagonal pieces, about $\frac{1}{4}$ of an inch in diameter, and almost as thin as paper. Pyrite nodules, $\frac{1}{2}$ of an inch or less in diameter, are common----- 1 0
°*Paradoxides davidis* Salter (c).
Agnostus laevigatus terranovicus Matthew (c).
Agnostus cf. *fallax* Linnarsson (r).
Agnostus granulatus (Barrande) (r).
Agnostus sulcatus Illing (a).
Agnostus cf. *acadicus declivis* Matthew (r).
93. Thin-bedded soft pyritiferous black shale----- 1 6
Paradoxides sp. undet. (possibly *P. davidis* Salter) (r).
Agnostus aevigatus ciceroides Matthew (c).
°*Agnostus laevigatus terranovicus* Matthew (a).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus cf. *granulatus* (Barrande) (r).
Agnostus cf. *sulcatus* Illing (a).
°*Agnostus* cf. *umbo* Matthew (r).
Stenotheca sp. undet. (c).
This is the lowest bed of the "Paradoxides davidis zone" of this paper.
92. Dark gray limestone----- 0 4
Agnostus cf. *acadicus declivis* Matthew (r).
Acrotreta misera (Billings) (r).
This is the top bed of the "Paradoxides hicksi zone" of this paper.
91. Soft pyritiferous black shale with limy lenses and nodules in its upper part----- 0 11
Solenopleura cf. *applanata* (Salter) (r).

- /Liostracus globiceps jaculator* n. var. (r).
Agnostus lævigatus ciceroideus Matthew (c).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus cf. *sulcatus* Illing (c).
Agnostus granulatus (Barrande) (r).
Agnostus cf. *umbo* Matthew (r).
/Agnostus cf. *parvifrons* Linnarsson (r).
/Agnostus fissus Lundgren MS (r).
Acrotreta misera (Billings) (r).
Stenotheca sp. undet. (r).
99. Soft pyritiferous black shale, slightly greenish in spots.
 Contains nodules of pyrite, some of which are as
 much as 1 inch in diameter----- 0 9
Paradoxides hicksi Salter (r).
Agnostus lævigatus ciceroideus Matthew (r).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus granulatus (Barrande) (r).
 °*Agnostus* cf. *sulcatus* Illing (a).
 °*Agnostus* cf. *umbo* Matthew (r).
 °*Agnostus* cf. *parvifrons* Linnarsson (r).
Agnostus fissus Lundgren MS (r).
/Agnostus cf. *gibbus* Linnarsson (r).
Acrotreta misera (Billings) (r).
89. Soft pyritiferous black shale with layers of brownish
 shale in its lowest inch----- 0 7
Paradoxides hicksi Salter (r).
Agnostus lævigatus ciceroideus Matthew (r).
Agnostus cf. *fallax* Linnarsson (va).
Agnostus fissus Lundgren MS (r).
88. Pyritiferous black shale, harder than bed 89----- 0 10
Paradoxides hicksi Salter (c).
Solenopleura cf. *applanata* (Salter) (r).
 °*Bailliella venulosa* (Salter) (c).
Agnostus lævigatus ciceroideus Matthew (r).
Agnostus cf. *fallax* Linnarsson (va).
Agnostus cf. *acadicus declivis* Matthew (r).
Agnostus rex (Barrande) (r).
Agnostus granulatus (Barrande) (r).
Agnostus fissus Lundgren MS (r).
 °*Agnostus* cf. *gibbus* Linnarsson (r).
Acrotreta misera (Billings) (r).
87. Soft pyritiferous black shale----- 1 5
Paradoxides hicksi Salter (c).
Centropheura sp. undet. (r).
/Conocorpyhe æqualis Linnarsson (r).
/Agrauios socialis Billings (r).
Agnostus lævigatus ciceroideus Matthew (c).
Agnostus cf. *fallax* Linnarsson (r).
Agnostus fissus Lundgren MS (r).

86. Pyritiferous black shale, slightly brownish in some layers and greenish blue in the bottom inch----- 1 2
Paradoxides hicksi Salter (r).
 °*Centroleura venusta* (Billings) (r).
Solenopleura cf. *applanata* (Salter) (a).
 °*Liostracus globiceps jaculator* n. var. (r).
Conocoryphe æqualis Linnarsson (r).
Agraulos socialis (Billings) (r).
Eodiscus punctatus (Salter) (c).
Agnostus cf. *fallax* Linnarsson (r).
Hyalolithid gen. and sp. undet. (r).
85. Pyritiferous black shale, harder than bed 86. Breaks with a conchoidal fracture----- 0 8
Paradoxides hicksi Salter (r).
Solenopleura cf. *applanata* (Salter) (r).
Agnostus fissus Lundgren MS (r).
84. Alternating beds of dark gray limestone and thin-bedded, soft, pyritiferous gray and bluish gray shale 1 4
Paradoxides hicksi Salter (c).
Centroleura sp. undet. (r).
Solenopleura cf. *applanata* (Salter) (a).
Conocoryphe æqualis Linnarsson (a).
Agraulos socialis Billings (c).
Eodiscus punctatus (Salter) (a).
Agnostus lævigatus ciceroides Matthew (c).
Agnostus cf. *fallax* Linnarsson (c).
Agnostus cf. *acadicus declivis* Matthew (c).
Agnostus fissus Lundgren MS (r).
Hyalolithid gen. and sp. undet. (r).
83. Soft olive shale----- 0 3
Paadoxides hicksi Salter (c).
Solenopleura cf. *applanata* (Salter) (r).
Conocoryphe æqualis Linnarsson (c).
Agraulos socialis Billings (c).
Eodiscus punctatus (Salter) (c).
82. Soft pyritiferous bluish black shale. Some of the pyrite occurs as small nodules. The fossils are poorly preserved----- 1
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (c).
Hyalolithid gen. and sp. undet. (c).
81. Thin-bedded dark gray shale, containing a few small flat phosphatic "pebbles"----- 1 1
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (a).
Eodiscus punctatus (Salter) (c).
 °*Agnostus lævigatus ciceroides* Matthew (r).
Agnostus cf. *fallax* Linnarsson (r).
Agnostus cf. *acadicus declivis* Matthew (r).
 /*Agnostus barrandei* Salter (r).

- Agnostus fissus* Lundgren MS (c).
/ *Acrothele* cf. *matthewi* (Hartt) (r).
80. Gray shale, greenish in spots. Occasional thin lenses of limestone or limy shale occur in its upper part, and 4 inches above the base there is a $\frac{1}{2}$ -inch bed of hard gray limestone or limy shale with uneven upper and lower surfaces.----- 0 7
 Paradoxides hicksi Salter (c).
 Solenopleura cf. *applanata* (Salter) (r).
 Agraulos socialis Billings (c).
 Agnostus cf. *acadicus declivis* Matthew (r).
 Agnostus granulatus (Barrande) (r).
 Agnostus barrandei Salter (r).
 / *Agnostus* cf. *parvifrons tessella* Matthew (r).
 Hyalolithid gen. and sp. undet. (r).
79. Hard dark gray shale, with a 1-inch bed of dark gray limestone at the top. The bedding surfaces of the shale are rough.----- 0 4
 Conocoryphe cf. *æqualis* Linnarsson (r).
 Agnostus rex (Barrande) (r).
 Hyalolithid gen. and sp. undet. (r).
78. Soft black shale, full of fragments of agnostids, most of which are too imperfect for specific identification.----- 0 1
 Paradoxides hicksi Salter (r).
 Agnostus fissus Lundgren MS (c).
77. Dark gray shale, containing small concretions of pyrite and thin lenses and nodules of limestone. The shale weathers brown.----- 0 7
 Paradoxides hicksi Salter (c).
 Agraulos socialis Billings (c).
 Solenopleura cf. *applanata* (Salter) (c).
 Agnostus cf. *acadicus declivis* Matthew (r).
 Agnostus barrandei Salter (r).
 Agnostus fissus Lundgren MS (r).
 Hyalolithid gen. and sp. undet. (r).
76. Soft dark blue shale, containing a few small black, probably phosphatic, nodules. The contained fossils are poorly preserved.----- 0 7
 Paradoxides sp. undet. (probably *P. hicksi* Salter (c).
 Agraulos socialis Billings (r).
 Agnostus cf. *acadicus declivis* Matthew (c).
 Agnostus sp. undet. (r).
75. Hard, brown-weathering, dark gray shale, containing a few small concretions of pyrite and (in its upper half) occasional thin lenses and nodules of dark gray limestone. Some of the bedding planes have rough surfaces. The fossils are poorly preserved.----- 1 4
 Paradoxides hicksi Salter (r).
 Agraulos socialis Billings (r).
 Eodiscus punctatus (Salter) (r).

74. Thin-bedded soft black shale, containing a few small black, probably phosphatic, nodules, an inch or less in diameter----- 0 3
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (c).
Agnostus cf. *acadicus declivis* Matthew (c).
Agnostus granulatus (Barrande) (r).
Agnostus fissus Lundgren MS (c).
Lingulella ferruginea Salter (r).
Stenotheca sp. undet. (r).
Hyalolithid gen. and sp. undet. (c).
73. Hard pyritiferous greenish gray and brownish gray, brown-weathering, shales, alternating with black shales----- 0 8
Paradoxides hicksi Salter (a).
Agraulos socialis Billings (a).
Agnostus sp. undet. (r).
Hyalolithid gen. and sp. undet. (c).
72. Soft dark gray, brown-weathering shale----- 0 2
Agraulos socialis Billings (r).
Agnostus fissus Lundgren MS (r).
71. Hard, tough, dark gray shale, weathering brown----- 0 2
Solenopleura ? sp. undet. (c).
Agraulos socialis Billings (c).
Agnostus cf. *acadicus declivis* Matthew (c).
70. Hard dark gray shale, weathering brown----- 0 2
Paradoxides hicksi Salter (a).
Agraulos socialis Billings (a).
Solenopleura ? sp. undet. (va).
Agnostus cf. *acadicus declivis* Matthew (r).
Agnostus nudus (Beyrich) (r).
Agnostus barrandei Salter (r).
69. Soft dark gray shale, weathering brown----- 0 9
Paradoxides hicksi Salter (a).
Solenopleura cf. *applanata* (Salter) (r).
Agraulos socialis Billings (a).
Eodiscus punctatus (Salter) (r).
Agnostus cf. *nudus* (Beyrich) (r).
Agnostus fissus Lundgren MS (c).
Brachiopod gen. and sp. undet. (r).
68. Dark gray limestone----- 0 1
No fossils found.
67. Greenish gray shale----- 0 3
Paradoxides hicksi Salter (a).
Solenopleura cf. *applanata* (Salter) (r).
Agraulos socialis Billings (a).
Conocoryphe cf. *æqualis* Linnarsson (r).
Eodiscus punctatus (Salter) (va).
66. Dark bluish gray shale with a 1-inch limestone bed an inch below the top. The shale contains small black, probably phosphatic, nodules, an inch or less in

diameter -----	0	5
<i>Paradoxides hicksi</i> Salter (a).		
<i>Agraulos socialis</i> Billings (c).		
<i>Agnostus</i> sp. undet. (r).		
65. Soft blue, brown-weathering shale with a 1-inch bed of limestone 2 inches above the base -----	0	6
<i>Paradoxides hicksi</i> Salter (c).		
<i>Agraulos socialis</i> Billings (c).		
<i>Agnostus</i> cf. <i>fallax</i> Linnarsson (r).		
<i>Agnostus rex</i> (Barrande) (r).		
<i>Agnostus barrandei</i> Salter (r).		
64. Soft, slightly pyritiferous, bluish gray shale, weather- ing brown -----	0	4
<i>Paradoxides hicksi</i> Salter (c).		
<i>Agraulos socialis</i> Billings (c).		
<i>Agnostus barrandei</i> Salter (r).		
<i>Agnostus</i> cf. <i>fallax</i> Linnarsson (r).		
<i>Agnostus fissus</i> Lundgren MS (c).		
63. Dark gray limestone -----	0	3
No fossils found.		
62. Heavy-bedded, brown-weathering blue shale, becoming a limestone in its lower inch at some places along it outcrop -----	0	6
<i>Paradoxides hicksi</i> Salter (c).		
<i>Agraulos socialis</i> Billings (c).		
61. Soft, thin-bedded, dark blue shale, weathering brown --	0	2
<i>Paradoxides hicksi</i> Salter (r).		
<i>Agraulos socialis</i> Billings (r).		
60. White clay, containing small pieces of soft dark blue shale -----	0	2½
No fossils found.		
59. Soft, thin-bedded, dark blue shale, similar to the shale in bed 60 -----	0	1½
No fossils found.		
58. Heavy-bedded, hard, tough, brownish gray shales, alter- nating with thinner-bedded black shales. Some of the bedding surfaces are smooth and some are rough. Occasional thin nodules of dark gray lime- stone, up to 1 foot or more in diameter, occur in the shale -----	0	8
<i>Paradoxides hicksi</i> Salter (a).		
<i>Agraulos socialis</i> Billings (a).		
<i>Agnostus fissus</i> Lundgren MS (c).		
<i>Agnostus barrandei</i> Salter (r).		
57. Soft pyritiferous black shale, the upper 6 inches softer and more fossiliferous than the lower 5 -----	0	11
<i>Paradoxides hicksi</i> Salter (c).		
<i>Centropleura</i> ? sp. undet. (r).		
<i>Solenopleura</i> cf. <i>applanata</i> (Salter) (r).		
<i>Agraulos socialis</i> Billings (c).		
<i>Agnostus</i> cf. <i>acadicus declivis</i> Matthew (r).		

Agnostus rex (Barrande) (r).

Agnostus fissus Lundgren MS (a).

Agnostus barrandei Salter (r).

Brachiopod gen. and sp. undet. (r).

Hyolithid gen. and sp. undet. (r).

56. Thin-bedded, hard, brown-weathering dark gray shale,
with a ½-inch bed of dark gray limestone at the top 1 0

Paradoxides hicksi Salter (c).

Agraulos socialis Billings (c).

Agnostus cf. acadicus declivis Matthew (r).

55. Dark gray shale, weathering brown----- 0 10

Paradoxides hicksi Salter (c).

Solenopleura cf. applanata (Salter) (r).

Agraulos socialis Billings (a).

Agnostus cf. acadicus declivis Matthew (c).

Agnostus barrandei Salter (r).

Alga ? (a).

54. Soft black shale. Not as soft as the soft black shales
of the lower part of the *Paradoxides davidis* zone--- 0 11

Paradoxides hicksi Salter (r).

Agraulos socialis Billings (c).

Eodiscus punctatus (Salter) (r).

Agnostus cf. acadicus declivis Matthew (a).

53. Dark gray shale, with a few thin black shales in the
upper part ----- 0 4

Paradoxides hicksi Salter (a).

Agraulos socialis Billings (va).

Agnostus cf. acadicus declivis Matthew (c).

Alga ? (a).

52. Dark gray shale, weathering brown. Contains a few
thin nodules of gray limestone near its base, and a
very few small, yellow-weathering, pyritiferous
masses, like those shown in beds 50 and 51----- 0 11

Paradoxides hicksi Salter (a).

Paradoxides cf. abenacus Matthew (r).

Agraulos socialis Billings (va).

Eodiscus punctatus (Salter) (r).

Agnostus cf. fallax Linnarsson (r).

Agnostus cf. acadicus declivis Matthew (c).

Agnostus rex (Barrande) (r).

Alga ? (r).

51. Dark gray, brown-weathering, shales, greenish in
places, with a ¼-inch bed of dark gray limestone
2 inches above the base. Contains a very few yellow-
weathering pyritiferous masses, like those in beds
50 and 52----- 1 5

Paradoxides sp. undet. (r).

Paradoxides hicksi Salter (r).

Paradoxides cf. abenacus Matthew (r).

Agraulos socialis Billings (va).

Eodiscus punctatus (Salter) (r).

- Agnostus cf. acadicus declivis* Matthew (c).
Agnostus granulatus (Barrande) (r).
Agnostus fissus Lundgren MS (r).
Agnostus barrandei Salter (r).
 Hyolithid gen. and sp. undet. (r).
 Alga ? (r).
50. Dark gray shale, containing a very few of the small, yellow-weathering, pyritiferous masses that occur commonly in the beds below. In beds 50 to 52 these masses are smaller than in some of the lower beds, being only an inch or less in diameter. This bed is slightly harder than bed 51----- 1 0
Paradoxides sp. undet. (r).
Agraulos socialis Billings(va).
Agnostus cf. parvifrons tessella Matthew (c).
49. Thinly and evenly bedded black shale----- 0 4
Paradoxides cf. eteminicus Matthew (r).
Paradoxides hicksi Salter (c).
Agraulos socialis Billings(va).
Agnostus sp. undet. (r).
48. Soft black shale, full of agnostids----- 0 1
°Solenopleura cf. applanata (Salter) (r).
Agnostus cf. acadicus declivis Matthew (c).
Agnostus barrandei Salter (r).
°Agnostus cf. parvifrons tessella Matthew (a).
°Agnostus cf. gibbus hybrida Brögger (va).
°Acrotreta misera(Billings) (a).
 Hyolithid gen. and sp. undet. (a).
 The presence of this soft black shale, full of agnostids—especially *Agnostus cf. gibbus hybrida*, which is not known to occur elsewhere in the section—among heavier gray shales with comparatively few agnostids, is noteworthy.
47. Thin-bedded gray and olive gray shales----- 0 1
Paradoxides sp. undet. (c).
Agnostus barrandei Salter (r).
 Alga ? (c).
46. Hard gray shale----- 0 1
Paradoxides hicksi Salter (a).
Agraulos socialis Billings (a).
Agnostus rex (Barande) (r).
Agnostus granulatus (Barrande) (r).
45. Heavy-bedded, hard, grayish black shale, containing a few small lens-shaped, yellow-weathering, pyritiferous masses, like those in beds 50 to 52----- 0 7
Paradoxides sp. undet. (r).
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (va).
Agnostus cf. fallax Linnarsson (r).
Agnostus cf. nudus (Beyrich) (r).

°Alga ? (c).

44. Thin-bedded blackish gray and brownish gray shale, blacker and heavier-bedded below than above, and containing a few small lens-shaped, yellow-weathering, pyritiferous masses----- 0 8
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (va).
Eodiscus punctatus (Salter) (r).
Agnostus acadicus declivis Matthew (r).
 °*Agnostus cf. nudus* (Beyrich) (r).
Agnostus rex (Barrande) (r).
Stenothecha sp. undet. (r).
43. Hard, brown-weathering gray shale, heavy-bedded in its lower half, but somewhat thinner-bedded above--- 0 11
Paradoxides hicksi Salter (c).
Agraulos socialis Billings (va).
 °*Agnostus cf. fallax* Linnarsson (r).
Agnostus acadicus declivis Matthew (r).
Agnostus rex (Barrande) (r).
Agnostus granulatus (Barrande) (r).
Agnostus barrandei Salter (c).
Hyalolithid gen. and sp. undet. (r).
42. White clay, underlain by ½ inch of gray shale, having an uneven upper surface----- 0 1
 No fossils found.
41. Thin-bedded, brown weathering, gray shale, containing occasional thin lenses of dark gray limestone, and numerous thin sheets of yellow-weathering, probably pyritiferous, material, some of which are a foot or more across. The bottom ½ inch of the bed is hard gray shale. The fossils are well preserved----- 0 6
Paradoxides sp. undet. (possibly *P. bennetti* Salter) (r).
Paradoxides hicksi Salter (c).
 /*Conocoryphe elegans* (Hartt) (r).
Agraulos socialis Billings (c).
Agnostus cf. acadicus declivis Matthew (r).
 °*Agnostus fissus* Lundgren MS (c).
 °*Agnostus barrandei* Salter (c).
Lingulella ferruginea Salter (r).
Hyalolithid gen. and sp. undet. (r).
 The faunas of this bed and of beds 37 to 40 are somewhat transitional between the typical *bennetti* and *hicksi* faunas.
40. Dark gray, brown-weathering shale, softer than the beds just below, and having uneven bedding planes, especially in its lower half. Contains a few thin limy lenses, and many scattered crystals of barite, about ¼ of an inch long----- 2 3
Paradoxides hicksi Salter (r).
 /*Liostracus tener* (Hartt) (va).

- Conocoryphe elegans* (Hartt) (c).
Agraulos socialis Billings (r).
^o*Eodiscus punctatus* (Salter) (r).
^o*Agnostus* cf. *academicus declivis* Matthew (r).
Lingulella ferruginea Salter (c).
39. Hard, heavy-bedded, very dark gray shale, weathering black ----- 1 6
Paradoxides sp. undet. (r).
Liostracus tener (Hartt) (r).
Lingulella ferruginea Salter (c).
38. Hard, heavy-bedded, very dark gray shale, weathering black. Contains many small crystals of barite and numerous small black concretions of undetermined chemical composition ----- 1 6
Liostracus tener (Hartt) (c).
Lingulella ferruginea Salter (c).
37. Hard, tough, heavy-bedded, dark gray shale, containing thin lenses and beds of dark gray limestone. Has a 1-inch bed of nodular shale at the base. Beneath one of the limestone beds, 5 inches above the base are 2 or 3 inches of bluish shale with an uneven upper surface, but no evidence of ripple marks or erosion-- 0 9
^o*Paradoxides hicksi* Salter (r).
^o*Agraulos socialis* Billings (c).
Lingulella ferruginea Salter (a).
36. One-half inch of soft blue shale, underlain by 1½ inches of unctuous white clay. The clay, like the similar, but thinner ones, in the beds above, is probably the result of the weathering of a shale bed----- 0 2
 No fossils found.
 This is the lowest bed of the "*Paradoxides hicksi* zone of this paper.
35. Shaly, nodular, dark gray limestone----- 1 0
Paradoxides sp. undet. (probably *P. bennetti* Salter) (r).
Paradoxides etemincus Matthew (c).
Liostracus tener (Hartt) (c).
Bailiella cf. *baileyi* (Hartt) (r).
Harttella matthewi (Hartt) (r).
Lingulella ferruginea Salter (a).
Acrothele matthewi (Hartt) (c).
 This is the top bed of the "*Paradoxides bennetti* zone" of this paper.
34. Hard, well-bedded, brown-weathering, black shale, containing many small crystals of barite----- 1 1
Paradoxides sp. undet. (probably *P. bennetti* Salter) (r).
Paradoxides etemincus Matthew (a).
Liostracus tener (Hartt) (r).
Conocoryphe elegans (Hartt) (r).
Bailiella cf. *baileyi* (Hartt) (r).

- Harttella matthewi (Hartt) (r).
 Lingulella ferruginea Salter (va).
 Acrothele matthewi (Hartt) (c).
 Brachiopod gen. and sp. undet. (r).
 This bed is remarkable for an abundance of
 brachiopods and a comparative scarcity of trilobites.
33. Olive shale, breaking with a conchoidal fracture and
 full of small nodules of gray limestone----- 0 5
 Paradoxides sp. undet. (probably *P. bennetti*
 Salter) (r).
 Paradoxides eteminicus Matthew (a).
 Liostracus tener (Hartt) (r).
 Bailiella cf. baileyi (Hartt) (r).
 Lingulella ferruginea Salter (c).
 Acrothele matthewi (Hartt) (c).
32. Olive shale, breaking with a conchoidal fracture and
 containing at some horizons many small limy nodules,
 which vary from 2 to 6 or more inches in diameter-- 1 1
 /Paradoxides bennetti Salter (r).
 Paradoxides eteminicus Matthew (a).
 Liostracus tener (Hartt) (r).
 Bailiella cf. baileyi (Hartt) (r).
 Harttella matthewi (Hartt) (r).
 Lingulella ferruginea Salter (c).
 Acrothele matthewi (Hartt) (c).
31. Olive shale, breaking with a conchoidal fracture and
 containing many small limy nodules in some of its
 layers ----- 2 9
 Paradoxides bennetti Salter (c).
 Paradoxides eteminicus Matthew (va).
 Liostracus tener (Hartt) (r).
 /Liostracus ouangondianus (Hartt) (r).
 Conocoryphe elegans (Hartt) (r).
 Bailiella cf. baileyi (Hartt) (r).
 Harttella matthewi (Hartt) (r).
 /Agnostus cf. fallax trilobatus Matthew (r).
 Agnostus cf. rex (Barrande) (r).
 Lingulella ferruginea Salter (c).
 Acrothele matthewi (Hartt) (c).
 Brachiopod gen. and sp. undet. (r).
30. Hard dark gray and olive gray shales, breaking with
 a conchoidal fracture ----- 1 10
 Paradoxides bennetti Salter (r).
 Paradoxides eteminicus Matthew (r).
 Liostracus tener (Hartt) (r).
 Lingulella ferruginea Salter (c).
 Acrothele matthewi (Hartt) (c).
 Brachiopod gen. and sp. undet. (r).
29. Hard, heavy-bedded, olive shale, with some of its layers
 full of limestone nodules----- 1 0
 Paradoxides bennetti Salter (c).

- Paradoxides etemicus* Matthew (a).
Liostracus tener (Hartt) (a).
Liostracus ouangondianus (Hartt) (a).
Conocoryphe elegans (Hartt) (r).
Bailiella cf. baileyi (Hartt) (r).
Harttella matthewi (Hartt) (c).
Agnostus cf. fallax trilobatus Matthew (r).
Agnostus cf. rex (Barrande) (c).
Agnostus granulatus (Barrande) (r).
Lingulella ferruginea Salter (c).
Acrothele matthewi (Hartt) (a).
Acrotreta gemmula Matthew (r).
28. Dark gray shale----- 1 7
Paradoxides bennetti Salter (c).
Paradoxides etemicus Matthew (a).
Liostracus tener (Hartt) (a).
Liostracus ouangondianus (Hartt) (c).
Conocoryphe elegans (Hartt) (c).
Harttella matthewi (Hartt) (r).
Agnostus granulatus (Barrande) (r).
Agnostus cf. rex (Barrande) (r).
Agnostus barlowi definitus n. var. (r).
Lingulella ferruginea Salter (r).
Acrothele matthewi (Hartt) (c).
Acrotreta cf. gemmula Matthew (r).
27. Olive shale full of limestone nodules----- 0 3
Paradoxides bennetti Salter (r).
Paradoxides etemicus Matthew (c).
Liostracus tener (Hartt) (c).
Conocoryphe elegans (Hartt) (r).
Harttella matthewi (Hartt) (c).
Eoorthis sp. undet. (r).
26. Hard olive shale, breaking with a conchoidal fracture-- 0 10
Paradoxides bennetti Salter (c).
Paradoxides etemicus Matthew (a).
Paradoxides parvovulus n. sp. (r).
Liostracus tener (Hartt) (c).
Liostracus ouangondianus (Hartt) (a).
Conocoryphe elegans (Hartt) (r).
Harttella matthewi (Hartt) (a).
Agnostus cf. fallax trilobatus Matthew (c).
Agnostus cf. exaratus tenuis Illing (r).
Agnostus cf. rex (Barrande) (a).
Agnostus barlowi definitus n. var. (r).
Lingulella ferruginea Salter (c).
Acrothele matthewi (Hartt) (c).
25. Olive shale, full of nodules of tough gray limestone . . . 0 4
Paradoxides etemicus Matthew (c).
Liostracus tener (Hartt) (r).
Conocoryphe elegans (Hartt) (r).
Bailiella cf. baileyi (Hartt) (r).

Harttella matthewi (Hartt) (c).
 Agnostus cf. rex (Barrande) (r).
 Eoorthis sp. undet. (r).
 Linguiella ferruginea Salter (r).

24. Tough, nodular gray limestone, with uneven upper and lower surfaces that are probably due to the nodular character of the bed and not to erosion----- 0 6
 Paradoxides bennetti Salter (c).
 Paradoxides eteminicus Matthew (c).

23. Hard, well-bedded, olive and bluish gray shale, breaking with a conchoidal fracture and containing occasional aggregations of tiny black, probably phosphatic, nodules and a few small concretions of pyrite. Holds many well preserved fossils, including some whole trilobites ----- 0 8

Paradoxides bennetti Salter (a).
 Paradoxides eteminicus Matthew (a).
 °Paradoxides parvocolus n. sp. (r).
 Liostracus ouangondianus (Hartt) (a).
 °Conocoryphe elegans (Hartt) (r).
 °Bailiella cf. baileyi (Hartt) (r).
 Harttella matthewi (Hartt) (a).
 Agnostus cf. fallax trilobatus Matthew (c).
 Agnostus cf. rex (Barrande) (a).
 °Agnostus granulatus (Barrande) (a).
 /°Agnostus claræ n. sp. (r).
 °Agnostus barlowi definitus n. var. (r).
 Lingulella ferruginea Salter (c).
 Acrothele matthewi (Hartt) (c).

Almost entire specimens of Paradoxides bennetti, Liostracus ouangondianus, Conocoryphe elegans, and Harttella matthewi were collected from this bed.

- 22 Olive shale, much slickensided against the nodular upper surface of bed 21----- 0 1

Paradoxides bennetti Salter (c).
 Paradoxides eteminicus Matthew (c).
 Harttella matthewi (Hartt) (a).
 /°Eoorthis cf. papias (Walcott) (r).

21. Hard, tough, nodular gray limestone, with uneven upper and lower surfaces, which are probably due to the nodular character of the bed and not to erosion. Contains scattered crystals of pyrite----- 0 7

Paradoxides bennetti Salter (r).
 Paradoxides eteminicus Matthew (c).
 /°Paradoxides lamellatus Hartt (r).
 Liostracus cf. ouangondianus (Hartt) (r).
 °Harttella matthewi (Hartt) (c).
 Lingulella ferruginæ Salter (r).
 Acrothele sp. undet. (r).
 °Acrotreta cf. gemmula Matthew (r).

/°*Micromitra* (*Iphidella*) cf. *ornatella* (Linnarsson) (r).

Stenotheca sp. undet. (r).

20. Alternating beds of greenish gray and bluish gray shales, which break with a conchoidal fracture and weather olive brown. They vary in hardness, but none of them are soft----- 82 0
 No fossils found.
 These unfossiliferous shales and the similar shales of beds 6 to 18, below, are in marked contrast with the generally richly fossiliferous shales of the rest of the section.
10. Two beds of tough, nodular, shaly gray limestone, 16 and 18 inches thick, with 6-inch beds of bluish gray shale between, above, and below them----- 4 5
 Paradoxides bennetti Salter (c).
 °*Paradoxides* cf. *etemicus* Matthew (c).
 Liostracus cf. *ouangondianus* (Hartt) (c).
 /°*Conocoryphe bullata* n. sp. (r).
 /°*Goniodiscus dawsoni* (Hartt) (r).
 Agnostus cf. *rex* (Barrande) (r).
 Lingulella ferruginea Salter (r).
 Eoorthis sp. undet. (r).
 Brachiopod gen. and sp. undet. (r).
18. Alternating beds of bluish gray and olive gray shales. The beds are usually several feet in thickness, and grade very gradually into each other----- 40 0
 No fossils found.
17. Bluish gray shales. Fossils very rare----- 15 0
 Liostracus cf. *ouangondianus* (Hartt) (r).
16. Alternating beds of light bluish gray and olive gray shales, grading very gradually into each other. The beds vary from a few inches to several feet in thickness, and sometimes change from the one color to the other along the strike----- 11 0
 No fossils found.
15. Olive gray shale, harder and heavier-bedded than 16, 17, and 18. A few of the beds contain numbers of lens-shaped cavities, 6 inches to 3 feet in diameter, which have probably been formed by the weathering of pyrite nodules. Fossils very rare----- 40 0
 Paradoxides sp. undet. (r).
 °*Liostracus* cf. *ouangondianus* (Hartt) (r).
 Hyolithid gen. and sp. undet. (r).
14. Dark bluish gray shale, weathering brown. More finely bedded than the shales of 13 and 15----- 2 0
 No fossils found.
13. Hard, heavy-bedded, olive shale, containing many black, probably phosphatic, nodules in some of its beds. Lenses of dark gray limestone, with uneven upper and lower surfaces, occur in the shales. These

lenses vary from a few inches to a foot or more in thickness, and are usually from one to four or more feet broad -----		6	0
Paradoxides bennetti Salter (r).			
12. Dark olive gray shale, not so hard as the shales of 11 and 13 -----		3	6
No fossils found.			
11. Hard, heavy-bedded, dark gray shale -----		4	6
No fossils found.			
10. Dark gray shale, not so hard as the shales of 8 and 11. Paradoxides sp. undet. (probably P. bennetti Salter) (r). Lingulella ferruginea Salter (r). Acrothele cf. matthewi (Hartt) (r). Hyolithid gen. and sp. undet. (r).		2	5
9. Dark olive gray shale, not so hard as the shales of 8 and 11. -----		1	0
No fossils found.			
8. Hard, heavy-bedded, bluish gray shale, weathering reddish brown on joint and bedding planes, and breaking with a conchoidal fracture. Contains a little manganese -----		2	2
Paradoxides bennetti Salter (r).			
°Ptychoparia rogersi Walcott (r).			
°Agraulos cf. affinis Billings (r).			
°Agnostus cf. fallax trilobatus Matthew (r).			
°Agnostus cf. rex (Barrande) (r).			
7. Hard, heavy-bedded, olive shale, breaking with a conchoidal fracture. Contains manganese and weathers black -----		1	6
Paradoxides bennetti Salter (r).			
6. Olive shale, softer than 4 and 7, and containing many small black, probably phosphatic, nodules. Contains some manganese and weathers black -----		1	6
°Paradoxides bennetti Salter (c).			
5. Olive shale, softer than 4 and 7, and full of fragments of a large trilobite. The shale contains some manganese and weathers black -----		0	1
Paradoxides ? sp. undet. (probably Paradoxides bennetti Salter) (va).			
4. Hard, tough, nodular manganiferous, calcareous, shale, with uneven upper and lower surfaces, which are apparently due to the nodular character of the bed and not to erosion. Contains many small black phosphatic nodules -----		0	5
Hyolithid gen. and sp. undet. (a).			
3. Hard, greenish gray shale, containing in some of its layers many small black phosphatic nodules, which are white when weathered -----		0	9
Paradoxides ? sp. undet. (probably Paradoxides bennetti Salter) (r).			

°*Lingulella* cf. *ferruginea* Salter (r).

°*Acrothele* cf. *matthewi* (Hartt) (r).

The small black nodules are not evenly distributed through the bed, but are usually arranged in bands or bunches. The fossils are found in the beds that hold the fewest nodules.

2. Hard dark blue shale, containing many small black phosphatic nodules, which are more abundant in some layers than in others.-----

1 3

Paradoxides ? sp. undet. (probably *Paradoxides bennetti* Salter) (r).

The fossils, which are rare and fragmentary, are found only in the layers in which the nodules are least abundant.

1. Hard, tough, nodular, manganiferous, argillaceous, dolomite. Has uneven upper and lower surfaces, which are probably due to the nodular character of the bed and not to erosion. Contains much phosphatic material, barite, and hematite. Fossils fragmentary -----

0 6

Brachiopod gen. and sp. undet. (r).

Hyolithid gen. and sp. undet. (r).

Sponge gen. and sp. undet. (r).

This is the bottom bed of the "*Paradoxides bennetti* zone," and therefore the lowest of the "*Paradoxides* beds" of this paper. It has been described in detail by Dr. Dale, as bed "219A11" (Dale, 1915, pp. 405-407).

Total thickness-----302 0

Further work will probably extend the vertical ranges of most of the species included in these faunal lists and will surely add many new names. There are at the present time in the Princeton collections from the *dauidis* zone at Manuel's the following six forms, which are not mentioned in these lists because the exact stratigraphical horizons from which they came are unknown: *Ctenocephalus coronatus* (Barrande), *Agnostus* cf. *planicauda* Angelin, *Agnostus bifurcatus* Illing, *Agnostus barlowi* Belt, *Agnostus rectangularis* n. sp., and *Acrotreta sacittalis* (Salter). Future studies will probably show in which beds these forms occur.

Of the 25 genera included in the above lists, 1 (*Protospongia*) is a sponge, 1 (*Hyolithes*) is a pteropod, 1 (*Stenotheca*) is a gasteropod, 6 (*Acrothele*, *Acrotreta*, *Eoorthis*,

Lingulella, Micromitra (Iphidella), and Obolus) are brachiopods, and the remaining 16 (Agnostus, Agrauios, Bailiella, Centropheura, Conocoryphe, Corynexochus, Ctenocephalus, Eodiscus, Gonioidiscus, Hartshillia, Harttella, Holocephalina, Liostracus, Paradoxides, Ptychoparia, and Solenopleura) are trilobites. Algæ are also probably represented.

DISCUSSION OF THE STRATIGRAPHY

The classification of the subdivisions of the Paradoxides beds at Manuels that is used in this paper is shown in Table I, p. 12. The beds are there referred to the Acadian epoch of the Cambrian period. In 1874 Murray wrote of the shales exposed in the gorge of Manuels Brook as "my Manuel's River rocks" (Weston, 1898, p. 153), and in 1889 Mr. Howley mentioned "the Manual Creek shales just above the Topsail Head limestone" (Howley, 1889, p. 123); but it is doubtful whether either of these authors intended to use their terms strictly in the sense of formation names; at any rate, they did not define them as such. In 1888 Dr. Walcott spoke of the Paradoxides beds of southeastern Newfoundland as the "Newfoundland" beds (Walcott, 1888a, p. 399). In 1914 Professor vanIngen (1914b) described the Paradoxides beds about Conception and Trinity Bays as the "Manuels series," composed of a single formation, which he called the "Manuels formation" (see Table III, p. 20). The known Paradoxides beds at Manuels and elsewhere in southeastern Newfoundland appear, however, to be divisible into at least three distinct formational units, and the writer therefore suggests, with Professor vanIngen's approval, that the term "Manuels" be abandoned as a formation name and retained in its larger sense alone. In the present paper Dr. Walcott's term "Newfoundland" is used as a general series name for all the Paradoxides beds of southeastern Newfoundland (some of which differ lithologically from the Paradoxides beds at Manuels), and Professor vanIngen's series name "Manuels" is restricted to the Paradoxides beds

of the Conception Bay region, where the lithological character of the beds appears to be everywhere approximately the same as it is at the type locality, Manuels. It is possible that the Paradoxides beds of Newfoundland do not represent a whole "series," in the sense in which that term was defined by the International Geological Congress of 1900; but the course suggested above would seem to be the best one to pursue at the present time. (This question is discussed further in Chapter VII.

The three major units into which the beds known to contain Paradoxides at Manuels seem to be most naturally divisible, both lithologically and faunally, are here named the Chamberlin's Brook formation, the Long Pond formation, and the Kelligrew Brook formation. The Chamberlin's Brook formation, which is the oldest of the three, outcrops in the banks of Chamberlin's Brook, a mile or two northeast of Manuels. It contains a fauna whose most characteristic species is the big trilobite, *Paradoxides bennetti*. (This species is perhaps identical with the earlier described one, *Paradoxides harlani* Green, of Massachusetts, and it is possible that the zone ought to be called the 'harlani zone'; but until the Newfoundland and Massachusetts fossils can be proved to be referable to a single species, it seems best to continue to use the name *bennetti*. See pages 60, 61). The Long Pond formation, whose type locality is on the shores of Long Pond, a couple of miles southwest of Manuels, is characterized by a smaller Paradoxides, *P. hicksi*. The Kelligrew Brook formation is exposed on the northeast side of the valley of Kelligrew Brook, about five miles southwest of Manuels. It is distinguished by the presence of another large trilobite, *Paradoxides davidis*.

It is not known whether these divisions should be considered as "stages" or as "zones" when measured by the stratigraphic units of the International Geological Congress. In the present paper they will be spoken of as "formations" or "zones." They are probably recognizable as lithologic units (formations) throughout the Conception

Bay region, and as faunal units (zones) throughout south-eastern Newfoundland. As no subdivisions of Acadian time that are applicable to the whole world have yet been defined by students of Cambrian history, it is not possible to refer these zones to any smaller universal time units.

The Chamberlin's Brook, Long Pond, and Kelligrew Brook formations grade gradually into each other. The same is true of the *bennetti*, *hicksi*, and *davidis* faunas. It has therefore been found necessary to draw the exact vertical boundaries between the zones more or less arbitrarily. The zones may be characterized briefly as follows, beginning with the highest:

III. *Paradoxides davidis* zone (Kelligrew Brook formation).

Beds 93 to 125; 31 feet thick.

Soft black and gray shales, the latter often containing flat nodules and lenses of dark gray limestone, which are sometimes as much as 6 feet in diameter and 1 foot in thickness. Small nodules of pyrite are common in the upper $4\frac{1}{2}$ feet. A bed, 1 to 2 inches thick and full of small black phosphatic nodules, occurs 24 feet above the base, and there is a similar, but slightly thicker, bed at the summit. Fossils are common in almost all of the beds and are very abundant in many of them, especially in the softer shales, which are often full of agnostids and other trilobites.

II. *Paradoxides hicksi* zone (Long Pond formation).

Beds 36 to 92; 37 feet thick.

The lower 25 feet are composed of heavy-bedded, brown-weathering and black-weathering, dark gray shales (with a few thin beds of soft black shale and some thin limy layers and lenses in their lower part) which grade upward into 10 feet of softer gray and black shales containing small lenses and nodules of limestone. Small concretions of pyrite occur at various horizons. The top is a 4-inch bed of dark

gray limestone; the bottom is a 1½-inch layer of unctuous white clay. Fossils are common in most of the beds, and agnostids are very abundant in many of the soft black shales.

I. *Paradoxides bennetti* zone (Chamberlin's Brook formation). Beds 1 to 35; 234 feet thick.

Hard olive gray, and somewhat softer bluish gray, shales, with several beds of impure nodular limestone. Two of the limestone beds are at the base, about two feet apart, a third is 134 feet above the base, and the others are scattered through the upper 13½ feet. A few of the shale beds in the upper 13½ feet are full of small limestone nodules. Small black phosphatic nodules, usually an inch or less in diameter, occur commonly in the lower 2 feet and 11 inches, and bodies of similar size and appearance, some or all of which are probably phosphatic, are found occasionally in the shales of the rest of the zone. Lens-shaped cavities, varying from a fraction of an inch to 6 inches or more in diameter and wholly or partly filled with a yellow earthy material that appears to have resulted from the weathering of pyrite concretions, occur at several horizons, especially in the 40 feet of olive gray shale that overlie the lower 28 feet. The shales break with a conchoidal fracture. The two lowest limestone beds (beds 1 and 4) are manganiferous. The shales are mostly barren except in the upper 13½ feet, where they contain many fossils and appear to be limier than below. The limestones are fossiliferous.

The beds of these three divisions appear to occur in an unbroken stratigraphic succession from the heavy-bedded, hard, olive gray and bluish gray shales of the *bennetti* zone, through the somewhat thinner-bedded, softer and darker shales of the *hicksi* zone, up to the predominately thin-bedded soft black shales of the *dauidis* zone. The shales of the *bennetti* zone usually weather to a very dark olive brown color, those of the *hicksi* zone to brown or brownish black,

and those of the davidis zone to black (except where stained brown by the weathering of pyrite). The limestones of the bennetti zone are generally light gray or pinkish in color, and occur in thin beds or in roughly oval or spheroidal nodules that appear to be of the same general type as the limestone nodules commonly found in the pre-Paradoxides beds of the Conception Bay region. The limestones of the hicksi zone are generally thinner than those of the bennetti zone, have smoother bedding planes, and occur usually as discontinuous sheets or thin lenses, rather than as continuous beds, and are dark gray, instead of light gray or pink, in color. In many ways they resemble the limestones of the overlying davidis zone, in which zone the limestones are not found as continuous beds, but as lenses and nodules, some of which are as much as a foot in thickness and six feet in diameter. Two beds filled with small masses of phosphatic material are present in the davidis zone—one at the top of the zone and the other 7 feet below it—and phosphatic bodies occur more or less abundantly in many of the shales of each of the three zones and in the two lowest limestones (beds 1 and 4) of the bennetti zone. The phosphatic bodies in the bed at the top of the davidis zone, and in the similar bed 7 feet below, sometimes contain fossils. Pyrite is common in all the zones, but is most abundant in the upper two. It usually occurs in small concretions and lenses, up to an inch or more in diameter, or in thin sheets, a small fraction of an inch thick. Some of the pyrite is associated with fossils. In a few instances hyolithid shells seem to have been filled with it. Barite is present in the dolomitic limestone (bed 1), at the bottom of the bennetti zone, and in the hard black shales of beds 38 and 40, near the base of the hicksi zone. In the latter two beds it occurs as little crystals, about $\frac{1}{4}$ of an inch long, scattered irregularly through the black shales. Thin beds of unctuous white clay, apparently derived from the decomposition of some sort of a shale, occur at several horizons in the hicksi and davidis zones.

The writer has discerned no good evidence of sub-ærial erosion in any part of the Paradoxides section at Manuels. The varied character of the sediments involved proves that the conditions of deposition changed from time to time. Some of the beds, such as the phosphatic ones at the base and summit, may possibly indicate some sort of stratigraphical break, for some or all of their phosphatic bodies may really be pebbles that have been rolled into place; but no good evidence of the erosion of any bed after its consolidation has been found, nor have any sun cracks or indubitable ripple marks been discovered. More field work will probably have to be done before these questions can be finally answered. The upper and lower surfaces of bed 1 are uneven. Dr. Dale (1915, p. 406) has stated that the upper surface is ripple marked, and when looked at in cross section, it does appear to be so; but in the late summer, when there is comparatively little water in the brook, several square yards of it are exposed, presenting evidence that the unevenness should probably be interpreted in a different way. The bed is divided by joint planes into roughly rectangular pieces with approximately square upper faces, so that, when viewed from above, it looks like a pavement of blocks. The upper face of each block has an area of about one square foot, and is slightly higher in the center than around the edges. Blocks whose upper portions have been removed by erosion show a black central core, which shows evidence of being more resistant than the rest of the mass, and seems to indicate that each block is essentially a nodule and that the unevenness of the upper and lower surfaces of the bed is due to these nodules rather than to ripple marking or erosion. Bed 4 shows the same features, although in a less pronounced degree, and beds 21 and 24 have similar, but less regular, nodular structures and uneven upper and lower surfaces. Bed 27 seems to be much like bed 24, except that its individual nodules have not originated near enough to each other, or have not grown large enough, to form a continuous bed of limestone, so that a shale full of limestone

nodules has resulted instead.

Bed 125 seems to have been interpreted by Dr. Walcott as a true basal conglomerate, for in notes on the Manuels Brook Cambrian section, published in 1900 (Walcott, 1900, p. 317), he says: "Six feet above the thickest band of limestone, in which *Paradoxides davidis* occurs, there is a thin layer of calcareous conglomerate, varying from 2 to 6 inches in thickness. It contains many dark argillaceous concretions, also pebbles of a reddish siliceous rock. This narrow band of conglomerate is found on both sides of the *ii* and is taken as the base of the Upper Cambrian. Of the fauna occurring below it one species of *Agnostus* and one brachiopod, *Obolus* (*Lingulella*) *ferruginea*, pass up into the *Olenus* fauna." The "thickest bed of limestone" mentioned in the first sentence of this quotation is probably a shale bed containing one or more of the large limestone lenses characteristic of the upper 7 feet of the *davidis* zone. A number of these lenses, lying end to end, might easily be mistaken for a part of a continuous stratum. The writer has not seen in bed 125 any of the "pebbles of a reddish siliceous rock" mentioned by Dr. Walcott. This bed should probably not be considered to be a conglomerate, in the usual sense of that term, because many of the pebbles, concretions, or whatever they may be, that occur in it appear to show by their shapes and positions that they could not have been rolled into place. It is true that the bed marks the line between the fossiliferous shales of the *Paradoxides davidis* zone and the superjacent barren measures of unknown age; but, that a deposit of this peculiar character does not necessarily prove the presence of an important sedimentary break, is suggested by the fact that the faunas of the shales that overlie and underlie the similar phosphatic "pebble" layer in bed 115 appear not to differ from each other in any appreciable way. However, as the only fossils that have been discovered in bed 125 occur in the masses of phosphatic material (none having been found in the surrounding matrix), it is possible that the phosphatic masses

of this bed are really fragments of older deposits. It seems more probable, however, that they are either concretions formed in the bed in which they now occur, or that they are pieces of unconsolidated contemporary or slightly older sediments that were being broken up at the time when bed 125 was being formed.

It is true that the *Agnostus pisiformis* and *Agnostus pisiformis obesus* ("Olenus") faunas, which occur not far above the *Paradoxides* beds in the brook section (see p. 27), appear to be fundamentally different from the *dauidis* fauna, and that there is, therefore, probably a stratigraphic break somewhere in the 30 or more feet of shales that lie between the highest beds known to contain *Paradoxides* and the lowest beds in which *Agnostus pisiformis* has been found; but this break may well occur somewhere above bed 125.

At the base of the *Paradoxides* section, the fossils of the *bennetti* zone seem to differ considerably from those of the underlying "*Catadoxides magnificus*" beds (see pp. 16 and 26), and some sort of a sedimentary break may very possibly exist in the 10 feet and 10 inches of unfossiliferous manganiferous shales that intervene between the lowest known *Paradoxides* bed and the highest known *Catadoxides* horizon.

These question will be taken up again in a future paper, in which the microscopical character, chemical composition, and mode of deposition of the *Paradoxides* beds of the Conception Bay region will be discussed in detail.

DISCUSSION OF THE CHARACTER AND OCCURRENCE OF THE FAUNAS

The general composition of the *Paradoxides* faunas at Manuels is shown in the faunal lists on pages 35 to 56 and in Table IV and the Manuels lists of Chapter VII. An examination of these lists and table will show that in each of the three zones the trilobites far exceed in both numbers

and variety all the other types of life. The number of individuals of each group (trilobites, brachiopods, etc.) in each zone is probably roughly proportional to the number of species present. It will be noted that almost all of the Newfoundland species are represented by identical or nearly identical forms in New Brunswick, Massachusetts, or Europe. The European and continental American types that have been recognized at Manuels are indicated in Table IV and discussed on pages 100-132.

Wherever Paradoxides faunas have been carefully studied, they appear to be roughly assignable to one or more of four large groups. Three of these four groups correspond to the *Paradoxides bennetti*, *Paradoxides hicksi*, and *Paradoxides davidis* faunas of Newfoundland; the fourth group, which is the youngest, is characterized by the presence of *Paradoxides forchhammeri*, and is known to be well developed only in Scandinavia. Possibly future work will demonstrate that this classification is not the most natural one, but it is a convenient one to use when discussing the faunas of southeastern Newfoundland and correlating them with their contemporaries in northwestern Europe and continental North America. At Manuels the *bennetti*, *hicksi*, and *davidis* faunas can each be divided into subfaunas; but, as the composition of some of these subfaunas may be due to very local facial conditions, it seems best to defer a discussion of them until more is known about the *Paradoxides* faunas of other Newfoundland localities.

The *bennetti*, *hicksi*, and *davidis* faunas are not sharply separated from each other in the Manuels Brook section, for their species frequently range from one fauna into the next. There seems to be no evidence of the sudden disappearance of a fauna except at the top of the *davidis* zone. There is good evidence of the more or less sudden arrival of new groups of species, such as the group characterized by *Paradoxides davidis* and *Agnostus punctuosus*, which appears abruptly in the bottom of the *davidis* zone; but, in

all known instances, a number of the species previously established in the region continued to exist there for some time after the arrival of the new forms. As a result of these conditions no bedding planes forming natural frontiers between the different zones have been discovered, and the stratigraphical limits here set to the zones are therefore of necessity chosen more or less arbitrarily, and may prove on further investigation not to be the best ones.

Of the 25 genera and 79 species and varieties identified by the writer in the Paradoxides beds at Manuels, 13 genera and 54 species and varieties have been found in one zone only, 9 genera and 8 species and varieties have been found in both the bennetti and hicksi zones, 8 genera and 16 species and varieties have been found in both the hicksi and davidis zones, and 6 genera and 4 species have been found in all three zones.

No member of any of the Paradoxides faunas has been recognized in beds below the bennetti zone at Manuels; but in the upper part of that zone there has been found a tiny brachiopod which appears to be referable to *Acrotreta gemmula* Matthew, a species occurring in the pre-Paradoxides beds of New Brunswick and Cape Breton (Walcott, 1912, p. 686). Dr. Walcott (1900, p. 317) has stated that two species (*Lingulella ferruginea* and an *Agnostus*) range up from the Paradoxides beds into the *Olenus* beds at Manuels (see p. 63).

No comprehensive discussion of the probable habitats and facial peculiarities of the Paradoxides faunas at Manuels will be attempted in the present paper, as it is believed that a full consideration of these subjects should be deferred until after further examinations have been made of the other exposures of Paradoxides beds in the Conception Bay region. A few observation on the distribution of the fossils in the different kinds of beds represented in the section can, however, properly be recorded at this time, and are therefore presented below.

DISTRIBUTION OF FOSSILS ACCORDING TO LITHOLOGICAL CHARACTER OF BEDS

Fossils are rare in the hard olive gray and bluish gray shales of the lower 220 feet of the bennetti zone, are common in the nodular limestones and the upper 14 feet of gray shales of that zone, and are usually common, and often abundant, in the gray shales of the hicksi and davidis zones. It is in the thin-bedded soft black and gray shales of the hicksi and davidis zones, however, that they occur in the greatest profusion, some of these beds being literally full of agnostids and other trilobites. They are rare in the upper 5 feet of heavy-bedded black and dark gray shales of the davidis zone and in the thin phosphatic bed (bed 125) at the top of that zone. Trilobites are the most abundant types in most of the beds, but they are outnumbered by the brachiopod, *Lingulella ferruginea*, at a few horizons in the heavy-bedded dark gray shales of the upper part of the bennetti, and the lower part of the hicksi, zones (beds 35, 37, 38, and 39). The limestone nodules and beds appear to hold the same species as do the shale beds in, or between which, they lie. It is probable that the limestone nodules were formed in the muds after the muds had been laid down and before they had become consolidated into shales; for the fossils in the limestones retain their convexity, where those in the surrounding shales are flattened, and the shales are often slickensided where they have settled down around the resistant nodules. The two limestones of bed 19 were perhaps deposited originally as impure lime muds. They contain many fossils, whereas the shales which precede and succeed them are almost entirely barren. The fauna which they contain is, however, not greatly different in its general composition from the one which occurs in the shale beds, 23 and 26, higher up in the bennetti zone.

The general rarity of fossils and the scarcity of limestones in most of the gray shales of the lower 220 feet of

the bennetti zone may both be due partly to the same cause, whatever that cause may be. The smaller fossils that are preserved in these shales frequently retain some or all of their convexity, but the larger ones, such as *Paradoxides bennetti*, are usually flattened and crumpled, as though the limy material that must have been originally present in their shells had been removed before the consolidation of the surrounding sediments. The question of chemical composition and method of preservation of the tests and shells of Cambrian organisms has been discussed in an interesting paper by Hicks (Hicks, 1875).

Considering the different types of fossils separately, we find that the larger trilobites, such as *Paradoxides*, *Conocoryphe*, *Bailiella*, *Harttella*, and *Centroleura*, are mainly confined to the harder, heavier-bedded, shales and the limestone beds and nodules. The trilobites of medium size, such as *Solenopleura*, *Liostracus*, *Agraulos*, and *Holocephalina*, are likewise found in the harder and heavier beds, but also occur commonly in the soft, thinly-bedded shales. The agnostids are most abundant in the soft black shales, from which most other trilobites are usually absent; but they are sometimes present in large numbers in the soft gray shales and the limestone nodules of the davidis zone. They are rare in the bennetti zone, where only 6 different forms have been discovered; they are common in the hicksi zone, 14 kinds having been found there, some of them in considerable numbers; and they are the most abundant and characteristic fossils of the davidis zone, which contains countless thousands of individuals, belonging to no less than 26 species and varieties.

The diversity of species of agnostids in the davidis zone may be more or less independent of the lithological character of the containing rocks, but the great abundance of individuals in some of the beds of that division, particularly in some of the black shales, surely must have some facial significance. Bed 48 and its fauna are especially interesting

in this connection. This bed, which occurs below the middle of the hicksi zone, is a soft black shale of the sort commonly found filled with agnostids in the lower part of the davidis zone, but very rare in the lower half of the hicksi zone, where most of the beds are somewhat heavily bedded gray shales containing relatively few of these little trilobites. Bed 48 is, however, as full of agnostids as a typical davidis zone black shale. Most of the agnostids present in the bed are found at other horizons in the hicksi zone, but the most abundant form, *Agnostus* cf. *gibbus hybrida* Brögger, has not been found at any other horizon at Manuels, and its presence in bed 48 is probably directly due to the black mud facial conditions obtaining at the time that that bed was deposited.

Agnostids are conspicuously absent from the olive and dark gray shales and the nodular limestones of the uppermost part of the bennetti zone (beds 32 to 35), and the hard, heavy-bedded, dark gray shales of the lower part of the hicksi zone (beds 36 to 39). Trilobites are comparatively rare in beds 36 to 39, and the absence of agnostids from those horizons is therefore not surprising. It is more difficult to imagine why they should be absent from beds 32 to 35, which contain many other trilobites.

The relative abundance of agnostids in the soft black and gray shales does not appear to be due to a better preservation of their tests in those kinds of deposits, for the individual specimens are no more perfect than the ones that are enclosed in the harder, heavier-bedded, gray shales. There does seem, however, to be a greater proportion of complete individuals in the softer shales, particularly in the black shales. This may indicate that the softer shales were deposited in quieter waters than the harder ones, although the harder, heavier-bedded, shales usually appear to be just as fine-grained as the softer ones. Remains of the larger trilobites, such as *Paradoxides* and *Centroleura*, are comparatively rare in the softer, thinner-bedded, shales, but when they do occur they are usually fairly well preserved,

so that their comparative scarcity in such beds would seem to be due, in some instances at least, to other causes than lack of conditions favorable to good preservation. For example, although specimens of *Paradoxides* are common in the soft black agnostid shales of beds 94, 95, and 96, they are usually absent from the soft black and gray shales of the lower part of the davidis zone, and have not been found at all in the black shale, bed 48, although occurring in large numbers in most of the other beds of that part of the section.

Of the brachiopods, *Lingulella ferruginea* and *Acrothele matthewi* are found most frequently in the hard, heavy-bedded, greenish gray shales of the bennetti zone and the equally hard and heavily bedded dark gray shales of the lower part of the hicksi zone, and *Acrotreta misera* is commonest in the soft black agnostid shales of the lower half of the davidis zone and in the similar shale of bed 48 of the hicksi zone.

Although there is this general relation between certain types of fossils and particular kinds of beds, yet beds of the same lithological character that are separated from each other by a bed, or beds, of a different sort seldom contain exactly the same faunas. For instance, three soft black shales in the lower half of the davidis zone may be, to all appearances, identical in lithological character, and may contain typical agnostid faunas, but each of the three faunas will differ slightly from the other two, and, when any species occurs in two of the beds, it is likely to be rare in one and abundant in the other.

Many species seem to have lived at Manuels only intermittently, for they appear in, and disappear from, the faunas there a number of times. In some cases the presence or absence of these forms seems to be due to the presence or absence of a particular type of sediment, but in other cases no such cause is apparent. For example, *Corynexochus minor* is found in beds 109 (a soft gray shale), 116 (a hard gray shale), and 119 (a black shale of medium hardness), but has not been discovered in any of the intervening

gray and black shales. The individuals occurring in beds 116 and 119 may possibly differ slightly from those in bed 109 and may perhaps belong to a variety of the species, but, if any differences exist, they must be small. Similarly, *Agnostus punctuosus* appears to be absent from beds 100 to 105, although it occurs (often in great abundance) in the overlying and underlying strata. *Agnostus granulatus*, with a much longer time range, is even more irregular in its occurrence. It has been recognized only in beds 23, 28, 29, 43, 46, 51, 74, 80, 88, 90, 91, 93, 94, 95, 99, 100, 101, 102, 105, 106, 107, 108, 109, and 110, but these beds include examples of the hard olive shales of the bennetti zone, the hard gray and the soft gray and black shales of the hicksi zone, and the soft black and gray shales of the davidis zone. The species was a long-lived one, with a wide geographical range (it has been reported from Bohemia, England, and Newfoundland), yet it seldom occurs in large numbers in any one of the beds of the Manuels Brook section. *Eodiscus punctatus* also has a remarkable vertical distribution, being present in beds 40, 44, 51, 52, 54, 67, 69, 75, 81, 83, 84, 86, 99, 101, 102, 103, 105, 106, 107, 108, 109, 112, and 115, but seemingly absent from the intervening beds. It shows a preference for gray, rather than black, shales, but sometimes occurs in the latter, and is frequently absent from the former. It is probable, however, that future work will disclose the presence of these four species, as well as many others, in beds which have so far yielded no traces of them.

In contrast to these species of intermittent range are others which seem to have lived continuously at Manuels, and to have been much less susceptible to the effects of changing environments. Such species sometimes range through a succession of beds of different lithological character. *Agraulos socialis*, one of the most characteristic members of the hicksi fauna, is one of these persistent types; *Paradoxides hicksi* is another.

On the whole, it seems likely that, although certain of

the members of the Paradoxides faunas were largely influenced by the changes that took place in the local environmental conditions at Manuels, others were very little affected by them; and the invasion of the district by new forms from some unknown outside region was probably the most important factor in bringing about the faunal changes that took place from time to time. Only a few of the species and varieties present in the hicksi and davidis faunas seem to have evolved from forms previously existing in the district; the majority appear to have been invaders from without. This matter is discussed further on pages 101-3.

IMPORTANCE OF AGNOSTIDS IN THE PARADOXIDES FAUNAS

Although the various species of Paradoxides are the most characteristic members of the Paradoxides faunas of the world, they are far surpassed in numbers and variety by the agnostids. Paradoxides supplies the best index fossils for the Paradoxides beds in general, and for the main faunal subdivisions in particular, because it is found all through the Paradoxides beds, is confined entirely to them, and is represented by different and widespread forms at different horizons. The agnostids are, however, usually the most useful group for distinguishing and identifying the smaller faunal divisions because of their great number and variety, their apparent ability to spread rapidly over large areas, and the ease with which their small shields are preserved entire, so that they can be specifically identified. Moreover, although they are most abundant in the Paradoxides beds (particularly in the hicksi, davidis, and forchhammeri zones), they are also found commonly in other Cambrian strata; and will probably prove ultimately to be one of the greatest aids in correlating not only the Paradoxides faunas, but also some of the later faunas of different parts of the world.

One of the most striking differences between the Paradoxides faunas and those which underlie them is that, while

the Paradoxides faunas contain agnostids, the others do not. Obviously the ancestors of the Paradoxidian agnostids must have lived in pre-Paradoxidian times, and their absence from the known pre-Paradoxides beds in all the regions where Paradoxides is known to occur indicates that the waters in which those older beds were deposited were either cut off by some barrier from the seas which contained agnostids at those times, or (what is less likely—for the later pre-Paradoxides beds, at least) that agnostids had not yet been evolved when those beds were laid down. Agnostids occur in Siberia, however, in faunas which may be of Catadoxidian (pre-Paradoxidian) age. (See vonToll, 1899.)

Agnostids occur in the beds which overlie the Paradoxides beds, but most of them are very different from those in the Paradoxides beds, and there are not nearly so many different species as there are in the Paradoxides faunas.

VI. DESCRIPTION OF NEW SPECIES FROM THE PARADOXIDES BEDS AT MANUELS

The following nine forms, believed to be new, have been discovered in the Paradoxides beds at Manuels in the course of the present investigation:

- Agnostus claræ.*
- Agnostus barlowi definitus.*
- Agnostus parvifrons punctifer.*
- Agnostus vaningeni.*
- Agnostus longifrons parvulus.*
- Agnostus rectangularis.*
- Conocoryphe bullata.*
- Paradoxides parvocolus.*
- Liostracus globiceps jaculator.*

These forms are described below and figured on Plate 3.

In describing the agnostids the writer employs the terminology of parts that has been in common use since Barrande's day. Professor Raymond has called attention to

the fact that paleontologists have perhaps been confusing the pygidia and cranidia of the agnostids, calling the pygidium the cranidium and vice versa (Raymond, 1917; 1920). The writer believes that this is possibly true, and that the question of which end of an *Agnostus* is which is still an open one. He feels, however, that such evidence as we have at present is more in favor of the long-accepted view than of Professor Raymond's newly-suggested one.

***Agnostus claræ*, new species**

Pl. 3, Fig. 1

Only the pygidium is known.

Pygidium, subquadrate, with a thin, tapering, sharply pointed, cusp or spine at each of the two posterior angles. Lateral lobes, wide, tapering and depressed behind the axis, but confluent, separating the rear end of the axis from the marginal furrow. Axis cylindrical, $7/10$ as long and $1/3$ as wide as the whole pygidium, nearly parallel-sided, but with a very slight constriction and faint indications of a transverse furrow at a point about $1/3$ of the way back from its forward end, evenly rounded posteriorly. Margin of moderate width all around. The marginal furrow and the furrow surrounding the axis are of moderate width and depth. In the single specimen known, which is slightly flattened, the axis is very convex, with some indications of a tubercle or keel on the anterior half. The side lobes are only slightly convex. The pygidium, as a whole, seems to have been a little higher at the front than at the rear. The ends of the spines at the posterior angles are broken off, but there is no evidence to indicate that they were unusually long. The surface of the test is smooth.

Length, 5mm. Breadth, 5 mm. at the rear, 6 mm. at the front. The greater breadth in front may be due to expansion on flattening, if the front was more convex than the rear.

Horizon, bed 23, in the upper part of the Paradoxides

bennetti zone. Very rare.

The specific name is given in honor of Mrs. Howell.

This species is based on a single pygidium, which is specimen 8000 in the paleontological collection of Princeton University. The most striking features of this pygidium are its quadrate form and its short, blunt, very convex axis. Of the agnostids that have been described from the Paradoxides beds of Europe and North America, *Agnostus fallax vir* Matthew (1886, p. 69; 1896, p. 215), of New Brunswick, and *A. fallax ferox* Tullberg (1880, p. 32), of Scandinavia, appear to approach it more closely. The tails of *vir* and *ferox* differ from that of *claræ* in having more tapering and slightly longer axes, and in being less quadrate in shape. The cranidium of *claræ* is unknown, but will probably prove to be more or less like that of *fallax vir*. Cranidia of that general type have been found in bed 23, but some or all of them probably belong to a form like *Agnostus fallax trilobatus* Matthew (1886, p. 68), pygidia of which occur commonly in that bed. Two cranidia (Nos. 8003 and 8025) of a similar form, but with the glabella only very faintly defined, also found in bed 23, may belong to *claræ*. It seems more probable, however, that they belong to another form, *Agnostus barlowi definitus*, and they are therefore described and discussed in the account of that species, which follows the present description. Until the cranidium of *claræ* is discovered, it will be impossible to assign the species definitely to any one of the numerous subdivisions into which different authors have proposed to split up the old genus, *Agnostus*. If it proves to have a *fallax*-like head, it will belong to Tullberg's subdivision, "Fallaces," of his group, "Limbatii" (Tullberg, 1880, p. 11), and to Corda's genus, *Peronopsis* (Hawle and Corda, 1847, p. 115; Raymond, 1913, p. 2; Zittel-Eastman, 1913, p. 710).

Agnostus barlowi definitus, new variety

Pl. 3, Figs. 2, 3

Only the pygidium is definitely known.

Pygidium semi-elliptical, about $\frac{1}{8}$ longer than wide, with a broad, shallow, marginal furrow and a somewhat convex margin. The margin is of medium width in front, but becomes very wide behind, where it bears two short, broad, sharply pointed cusps or spines. Lateral lobes of medium width, confluent behind the axis, where they are almost as broad as at the sides. Axis broad and very bluntly pointed; slightly constricted in its forward third, where it bears an elongated tubercle; widening rapidly toward the front where it reaches its greatest breadth. It is about $\frac{3}{7}$ as wide and $\frac{5}{7}$ as long as the whole pygidium, and is completely surrounded by a narrow, shallow furrow, which is often very weakly impressed around the rear half of the axis. The whole pygidium is of medium convexity, highest in the front half and sloping gradually toward the sides and rear.

Length, $3\frac{1}{2}$ to $4\frac{1}{2}$ mm. Breadth, $3\frac{1}{4}$ to $4\frac{1}{4}$ mm.

Horizons, beds 23, 26 and 28, in the upper part of the *Paradoxides bennetti* zone. Rare.

The holotype is specimen No. 8001 in the paleontological collections of Princeton University. It is from bed 23.

The varietal name refers to the fact that the axis is completely defined by a furrow.

This pygidium is very similar to that of *Agnostus barlowi spinatus* Illing (1916, p. 413). It differs from that form in having the axis completely defined by a furrow, instead of merely indicated by two short grooves near the front of the pygidium, in having the marginal border broader at the rear; and in having the cusps or spines farther back. *Barlowi spinatus* has been found only in the *hicksi* zone of England, while *barlowi definitus* is known to occur only in the upper part of the *bennetti* zone of Newfoundland. Only a few specimens of either form have been

discovered, and it is possible that a large series of specimens from either England or Newfoundland would show that the two varieties are one. However, as they occur at different horizons so that their varietal peculiarities may have some phylogenetic significance, it has seemed best to describe the Newfoundland form under a separate name.

The author has followed Illing's example in calling *definitus* a variety of *barlowi*. Whether *spinatus* and *definitus* are really varieties of *Agnostus barlowi* Belt (1868, p. 11) must remain an open question until the crinidium of either *spinatus* or *definitus* is discovered. There are two cranidia from bed 23 in the Princeton collections which may possibly belong to *definitus* (Nos. 8003 and 8025 in the paleontological collections of Princeton University; see plate 3, figure 3). They agree with Lake's (1906, p. 17) description of the head of *barlowi* except that they have a marginal fold of medium width, instead of the very narrow one of that form, and that a two-lobed glabella is faintly outlined, instead of having only the rear end of it suggested by short furrows, as in Belt's species. Lake's figure of *barlowi* seems to show a faintly outlined glabella, with no sign of a cross-furrow separating it into two lobes. It is barely possible that these two Newfoundland heads belong to *Agnostus claræ* (see description above), the head of which is unknown and may very well be of this type. They are referred to *barlowi definitus* mainly because *definitus* seems, from the number of pygidia found, to have been more common than *claræ* in the beds in which the heads were found. If the heads do belong to *barlowi definitus*, we would appear to have in the phylogeny of the *barlowi* line a progressive loss of furrows from both cranidium and pygidium, as well as a loss of spines from the pygidium—indicating, perhaps, a progressive loss of vitality in the race, resulting ultimately in extinction. Belt stated that the type specimens of *barlowi* came from the Tremadoc. Lake supposed that since *Agnostus cicer* Tullberg (1880, p. 26), which appears to be identical with *barlowi*, was recorded by Tullberg from the

Conocoryphe æqualis zone and *Agnostus intermedius* zone (both of which zones are well up in the *hicksi* zone), Belt must have been mistaken when he recorded *barlowi* from the Tremadoc. The finding of "cicer" in the *Paradoxides davidis* beds by Grönwall (1902, p. 167), of *spinatus* in the lower *hicksi* beds by Illing, and of *definitus* in the upper *bennetti* beds, as here recorded, indicates that the race may have been a long-lived one and may really have ranged up into the Tremadoc, after all.

Grönwall (1902, pp. 59, 60, 210) has described a variety of *barlowi* from the *davidis* zone of Bornholm Island, Denmark, which he has named "*cicer forfex*," the tail of which differs from *cicer*, as that of a *definitus* differs from that of a *spinatus*, in having the axes completely outlined. *Forfex*'s tail differs from that of *definitus* in having a more bluntly pointed axis, no spines, and a narrower marginal fold. *Barlowi*, *barlowi spinatus*, and *barlowi definitus* have unusually wide marginal folds, however. Belt notes how the wide fold of *barlowi* makes the species resemble *Agnostus nudus* (Beyrich), (Beyrich, 1845, p. 46; Barrande, 1852, p. 903), and this resemblance is even more striking in *definitus*, with its still wider border, widest at the rear.

***Agnostus parvifrons punctifer*, new variety**

Pl. 3, Figs. 4, 5

Only the pygidium is definitely known.

Pygidium semi-elliptical, about as wide as long, with a slightly convex margin, which is of medium width in front but becomes very broad at the rear, reaching its greatest breadth back of the rear end of the axis. Lateral lobes of medium width, tapering at the rear, not confluent. Axis of medium width, very slightly constricted near its anterior end, tapering backward to a fine point which separates the lateral lobes from each other and reaches the marginal furrow; very convex, reaching its greatest height in the middle, where it is prolonged upward and backward into a sharp-pointed, somewhat elongated, peak or super-tubercle, which

slopes toward the front of the pygidium at an angle of about 45° , slopes somewhat more steeply toward the sides, and has a very steep, concave slope toward the rear, the concavity being due to the fact that the peak bends backward so that it slightly overhangs the posterior slope. The lateral lobes and marginal fold are only very slightly convex, and the axis rises very prominently above them. The lateral lobes are separated from the axis and the marginal fold by furrows which are very wide and fairly deep in the type specimen, which is exfoliated, but which are probably very much less prominent—perhaps even indistinct—in unexfoliated specimens.

Length, 3 mm. Width, 3 mm. Height of the peak of the axis above the lateral lobes, 1 mm.

Horizon, bed 101, in the lower part of the davidis zone. Rare.

The holotype is specimen 8004 in the paleontological collections of Princeton University. The natural mold is specimen 8005.

The varietal name refers to the elongated tubercle borne on the axis.

The pygidium of this remarkable little agnostid is very similar to that of "*Agnostus parvifrons mammillata*" Brögger (1878, p. 56), appearing to differ from that form only in having the peculiar elevation of the middle of the axis more pronounced and slightly bent backward instead of being symmetrical. An immature pygidium $1\frac{1}{2} \times 1\frac{1}{2}$ mm. in size (specimen 8006 in the paleontological collections of Princeton University) found in the same bed as the type of *parvifrons punctifer* and probably belonging to that form, appears to differ in no essential respect from immature pygidia of "*parvifrons mammillata*" from Scandinavia contained in the Princeton collections (specimens 8009 and 8010).

The thorax and cranidium of *parvifrons punctifer* are not definitely known. The cranidium is probably like that of "*parvifrons mammillata*." An immature cranidium about

1¼ x 1¼ mm. in size (8008 in the Princeton collections), from the same bed as the holotype pygidium of *punctifer*, appears to differ in no way from an immature cranidium of "mammillata" on specimen 8010. It is similar to the adult head of "mammillata" figured by Brögger (1878, pl. V, fig. 3a), being semi-elliptical, rather convex, and surrounded by a margin of medium width, which is separated from the rest of the cranidium by a furrow that is of medium width and depth in this particular specimen, which is exfoliated, but would probably be much less distinct on an unexfoliated specimen. The glabella is very convex, slightly longer than wide, and is surrounded by a furrow of medium depth and width, which would probably be shallower on an unexfoliated specimen. The basal lobes are of medium size, and are confluent behind the glabella.

It is possible that the single pygidium upon which this new variety is based is a deformed or aberrant example of "parvifrons mammillata," as pygidia nearer to the normal "mammillata" type occur only a few feet higher in the section (in bed 74).

Agnostus parvifrons and its varieties appear to have been an extremely variable group, however, and it is quite possible that *punctifer* is a valid variety. Whether *punctifer* and *mammillata* should really be classed as varieties of *Agnostus parvifrons* Linnarsson (1869, p. 82) is perhaps an open question. It seems best to follow Brögger for the present, however, and consider them as such. If future research proves that the two are not varieties of *parvifrons*, then *punctifer* will become a variety of *mammillata*. Jækel (1909) has proposed the genus, *Hypagnostus*, for *Agnostus parvifrons* and its allies; and if that genus is accepted as defined by Jækel, *punctifer* will belong to it.

***Agnostus vaningeni*, new species**

Pl. 3, Fig. 6

Pygidium semi-elliptical, moderately and fairly evenly convex, surrounded by a margin of medium width and con-

vexity, which is separated from the rest of the tail by a shallow furrow of medium width. Axis large, $1\frac{1}{2}$ times as wide as the lateral lobes; long; evenly tapering, except at a point just back of the front end, where it is very slightly constricted; ending in a blunt point a short distance in front of the marginal furrow; separated from the lateral lobes by a narrow, shallow furrow; bearing a somewhat elongated tubercle about one-third of the way back from its forward end. Lateral lobes of medium width in front, tapering regularly to rather blunt points at the rear, where they are separated by a narrow, shallow furrow, which connects the furrow surrounding the axis with the marginal furrow. The whole pygidium is evenly and very moderately convex.

Length of the holotype pygidium, $3\frac{1}{2}$ mm.; breadth, $3\frac{1}{2}$ mm. Other specimens identified as belonging to this species (specimens 8013 and 8030) are 1 mm. or more larger. The axis of the holotype is 3 mm. long, and $1\frac{3}{4}$ mm. wide.

Horizon of the holotype, bed 99. Other specimens possibly belonging to this species (specimens 8031 and 8032) were found in beds 100 and 102. All of these beds are in the lower part of the davidis zone. Rare.

The holotype is specimen 8011 in the paleontological collections of Princeton University. The natural mold of the holotype is specimen 8012.

The specific name is given in honor of Professor Gilbert vanIngen.

The pygidium of this species resembles those of *Agnostus lævigatus terranovicus* Matthew (1896, p. 233), *Agnostus parvifrons tessella* Matthew (1886a, p. 71), and *Agnostus rotundus* Grönwall (1902, p. 78). From *lævigatus terranovicus* it is distinguished by its longer axis and the separation of its lateral lobes at the rear. It differs from *rotundus* in having a longer and wider axis, and tapering side lobes, completely separated at the rear. It is not greatly different from *parvifrons tessella* in general shape, but has a slightly wider and longer axis, the marginal furrow and

the furrow surrounding the axis are less distinct, and there are no distinct furrows crossing the axis, such as there are in that form.

Although the cranium of *Agnostus vaningeni* is unknown, it is probably more similar to that of *lævigatus terranovicus* and *rotundus* than to that of *parvifrons tessella*, as certain cranidia of the *terranovicus-rotundus* type occur in association with the *vaningeni* pygidia. Possibly *vaningeni* represents an intermediate stage of evolution between *parvifrons tessella* and *lævigatus terranovicus*. It is interesting to note, in this connection, that the unexfoliated pygidia of *vaningeni* look very much like those of *lævigatus terranovicus*, while exfoliated tails much resemble those of *parvifrons tessella*. *Vaningeni* is probably nearest to *terranovicus*, as its cranium is almost certainly of the *terranovicus* type. It may prove, however, to be even nearer to the British form which Lake (1906, p. 14) has referred to *rotundus*, but which, to judge from his figures and description, is perhaps nearer to *lævigatus terranovicus* than to *rotundus*. Perhaps *parvifrons tessella*, *vaningeni*, *lævigatus terranovicus*, and *lævigatus Dalman* (1828, p. 136) represent a single line of development, to a branch of which *rotundus* and the closely related Newfoundland form, *lævigatus mamilla* Matthew (Matthew, 1896, p. 234) may belong. *Agnostus lens* Grönwall (1902, p. 65) appears also to be very similar to *lævigatus terranovicus*, and, as *lens* is found at a horizon in Scandinavia that appears to be lower than the one at which *vaningeni* occurs in Newfoundland, it is possible that *terranovicus* is descended from *lens*, and not from *vaningeni*. *Vaningeni*, like *lævigatus terranovicus*, *lævigatus mamilla*, *lens*, *rotundus*, and the somewhat similar Paradoxidian form, *Agnostus lævigatus ciceroideus* Matthew (1896, p. 234), and the very similar or identical form, *Agnostus altus* Grönwall (1902, p. 58), together with *Agnostus lævigatus forfex* Brögger (1878, p. 58), *Agnostus barrandei* Salter (Hicks, 1872, p. 176), *Agnostus lens frontosa* Grönwall (1902, p. 66), *Agnostus barlowi* Belt (1868,

p. 11), *Agnostus barlowi* forfex Grönwall (1902, p. 59), *Agnostus barlowi spinatus* Illing (1916, p. 413), and *Ag. barlowi definitus* (described above, see p. 76), does not appear to fit into any of the genera of Jækel's or Professor Raymond's classifications. Some of them, such as *lævigatus terranovicus* and *lævigatus forfex*, are probably so closely allied to *lævigatus*, the type of Corda's genus, *Lejopyge* (Hawle and Corda, 1847, p. 51), that they should be classed in that genus, but the others should probably be assigned to one or more new genera. If *vaningeni* is really derived from *parvifrons tessella*, it is probable that *teseslla* belongs to a different group from *parvifrons* Linnarsson (1869, p. 82), and should not be called a variety of that species.

***Agnostus longifrons parvulus*, new species**

Pl. 3, Figs. 7, 8

Only the cranium is definitely known.

Cranidium small, semi-elliptical, evenly and moderately convex, surrounded by a narrow, convex margin, which is separated from the rest of the cranium by a narrow marginal furrow of medium depth. Glabella bilobed, parallel-sided, the front lobes separated by a straight furrow of medium width and depth. The glabella is surrounded by a deep, narrow furrow, which is continued forward in front of the front lobe, so that it joins with the marginal furrow and separates the two cheeks. The front lobe of the glabella is roughly triangular in shape, the two sides of the triangle being convex and the apex an obtuse angle. It is of moderate convexity, approximately the same as the cheeks. The rear lobe is about twice as long as wide; the front third is moderately convex, like the front lobe, but the posterior two-thirds is evenly and highly convex, and is crowned with a tubercle. The basal lobes are small and triangular. The cheeks are somewhat wider than the glabella, are moderately convex, of approximately equal width throughout, and are separated by a furrow in front of the glabella.

Length of the holotype cranium, 2 mm.; breadth, $1\frac{3}{4}$

mm. This is an average sized adult cranidium.

Horizon, bed 109, the middle part of the davidis zone.
Rare.

The holotype is specimen 8014 in the paleontological collections of Princeton University.

The varietal name refers to the small size of the variety.

The holotype of this variety is a cranidium. No well preserved and certainly identifiable complete individual has been discovered to prove beyond question just what the pygidium is like; but a poorly preserved specimen showing both cranidium and pygidium (specimen 8015 in the Princeton collections), which is almost certainly of this variety, and numerous little pygidia found associated with longifrons parvulus cranidia, enable us to be reasonably certain about the matter. The description of the pygidium given below is based upon an impression on a piece of shale (Princeton specimen 8016) broken from the piece holding the holotype cranidium, and upon pygidia found on Princeton specimens 8017, 8018, 8033, and 8037. Specimen 8033 and its counterpart 8037 hold a cranidium that is believed to belong to this species.

Pygidium small, semi-elliptical, surrounded by a margin of medium convexity and width, and by a shallow, narrow, marginal furrow. Axis convex, narrow, slightly constricted in its anterior third, tapering to a rounded point at the rear. It is divided into three segments. The anterior lobe is short. The middle segment is about the same length as the anterior one, but is expanded in the middle so that it juts forward and backward until it is nearly twice as long there as it is at the sides. It bears a prominent median tubercle or keel. The posterior segment is about twice as long as the two anterior segments combined, but does not reach the marginal furrow behind. The lateral lobes are convex, but not so much so as the axis; they are wider than the axis, and are somewhat narrowed behind, where they are separated by a narrow, shallow, furrow, which joins the marginal furrow to the narrow, but rather deep, furrow

that surrounds the axis. The pygidia have about the same general dimensions as the cranidia.

This form is very closely related to *Agnostus longifrons* Nicholas (1916, p. 453). It differs from *longifrons* in being smaller, in having the anterior lobe of the glabella shorter, and in having the posterior lobe of the glabella longer, with the greatest convexity $\frac{1}{3}$ of the length of the lobe forward from the posterior margin, instead of just in front of it. The pygidia of the two forms appear to be identical, except for size, and the thorax of *longifrons parvulus* will probably prove, when it is discovered, to be like that of *longifrons*.

Agnostus longifrons, which is a Welsh species, apparently occurs in the hicksi zone, while *longifrons parvulus* is found well up in the davidis zone. Mr. Nicholas has pointed out, in his description of *longifrons* (1916, p. 454), how this type of agnostid resembles *Agnostus gibbus* Linnarsson (1869, p. 81).

Agnostus longifrons parvulus is one of the smallest of all known agnostids, and therefore one of the smallest of known trilobites. It is perhaps the smallest trilobite yet discovered. It is almost surely descended from the *Agnostus longifrons* line. It belongs in the genus *Agnostus*, sens. strict., of Jækel's and Raymond's classifications.

***Agnostus rectangularis*, new species**

Pl. 3, Fig. 9

Only the cranidium is known.

Cranidium roughly rectangular, slightly longer than broad, with rounded corners. Margin broad and nearly flat. Marginal furrow broad and shallow. Cheeks of medium width, approximately equal in width throughout, confluent in front of the glabella. Glabella of medium length and width, about as wide as the cheeks, and two-thirds as long as the cranidium, not bilobed. It narrows slightly toward the front, where it is evenly rounded, and it is separated from the cheeks by a shallow furrow. The basal lobes are

large, triangular in shape, and rather indistinctly marked off from the rest of the glabella. There is a very indistinct tubercle on the glabella about $1/3$ of the way forward from the rear margin. The whole cranium is rather flat. It is highest at the rear.

Length of the holotype, $3\frac{1}{2}$ mm., breadth, $3\frac{1}{4}$ mm. The only other specimen known is 4 mm. long and $3\frac{1}{2}$ mm. broad.

Horizon, somewhere in the upper half of the davidis zone. Exact horizon unknown, but probably bed 115 or a nearby bed.

The holotype is specimen 8019 in the paleontological collections of Princeton University. The natural mould of the holotype is specimen 8039. The other specimen is numbered 8020.

The specific name refers to the rectangular appearance of the cranium.

At first glance, the cranium of this species reminds one of that of *Agnostus fallax* Linnarsson (1869, p. 81), because of its quadrate form and wide margin. *Fallax*, however, has a bilobed glabella. The cranium of *Agnostus obtusus* Belt (Belt, 1868, p. 10; Lake, 1906, p. 28) is similar to that of *rectangularis* in general shape, but it has, like *fallax*, a bilobed glabella. *Agnostus tardus* Barrande (1852, p. 913), and the closely related forms, *A. glabratus* Angelin (1878, p. 6) and *A. lentiformis* Angelin (1878, p. 7), have crania somewhat similar to that of *rectangularis*, as do *A. sidenbladhi* Linnarsson (1869, p. 82), *A. callavei* Raw MS., (Lake, 1906, p. 25), and *A. sallesi* Munier-Chalmas and Bergeron (Bergeron, 1889, p. 337). *Tardus*, *glabratus*, *lentiformis*, *sidenbladhi* and *callavei* are of much younger age than *rectangularis*, but *sallei* is from the Paradoxides beds of southern France. The figure and description of *sallei* given by Munier-Chalmas and Bergeron are not clear and detailed enough to show just how similar their species is to *rectangularis*, but they are sufficient to suggest that it is very close, so that the Newfoundland form may yet prove

to be a variety of the French one, or even identical with it. Rectangularis is probably referable to the genus *Arthrorachis* Corda of Raymond's classification.

The cranidium of *rectangularis* exhibited on specimen 8020 shows faint traces of two peculiar diagonal furrows on the front of the glabella in just the same position as those described and figured by Raw and Lake on the glabella of *callavei* (Lake, 1906, p. 26, pl. II, fig. 20). Lake states that these furrows may be adventitious cracks in *callavei*, and the same may be the case with the one cranidium of *rectangularis*. The holotype cranidium of *rectangularis* does not show any clear evidence of such furrows, although there appear to be slight indentations present, which may be traces of similar grooves. These furrows, if they really are such, the general character of the cranidium, and the presence in beds of the same, or nearly the same, horizon of pygidia somewhat resembling the pygidium of *Agnostus quadratus* Tullberg (1880, p. 34), suggest the possibility that *rectangularis* may prove to be related to *quadratus*, rather than to the other species mentioned above. To judge from Tullberg's figure, *quadratus* has a more pointed glabella than *rectangularis*, and shows more definite indications of furrows. The *quadratus*-like pygidia from Manuels also differ from the pygidium of *quadratus* in having much shorter axes. *Quadratus* occurs in the *Paradoxides forchhammeri* beds of Sweden, above the *Paradoxides davidis* beds, and perhaps *rectangularis* is an ancestor of *quadratus*.

The exact horizon of the *quadratus*-like pygidia found in loose limestone nodules at Manuels is not known, but it is somewhere in the *davidis* zone, and, to judge from the fossil evidence, from the same, or about the same, horizon as the *rectangularis* cranidia. A typical example of this sort of pygidium is shown on Princeton specimen 8038.

Conocoryphe bullata, new species

Pl. 3, Figs. 10, 11

Only the cranidium is known.

Cranidium roughly semicircular, twice as wide as long, with broad, upturned anterior and posterior margins and broad deep anterior and posterior marginal folds, and a nearly straight facial suture. Glabella conical; about $3/5$ as long as the whole cephalon, with probably three furrows (the only known specimens are imperfect and show only the forward part of the glabella). The glabella is surrounded by a furrow of medium depth and width. The cheeks are confluent in front of the glabella, where they are slightly convex. The main part of each fixed cheek is remarkably convex, reaching its greatest height opposite the middle of the glabella. The whole surface of the cephalon is covered with small tubercles, about 4 in each square millimeter. A small keel-shaped prominence on the outer front edge of the swollen portion of the cheek may be the rudiment of an ocular ridge.

Length of the holotype cranidium 1 cm., breadth, 2 cm. Height of elevated portion of fixed cheek above bottom of posterior marginal furrow just back of highest part of the fixed cheek, about 5 mm.

Horizon, bed 19, in the middle of the *Paradoxides benetti* zone. Rare.

The holotype is specimen 8021 in the paleontological collections of Princeton University. The natural mould of the holotype is specimen 8040. A smaller head, believed to be referable to this species (fig. 11), is numbered 8026.

The specific name refers to the bubble-like elevation of the fixed cheeks.

This *Conocoryphe* resembles *Conocoryphe dalmani* Angelin (1878, p. 63) in its general shape, but differs markedly from that species in its greatly elevated fixed cheek. This elevation of the fixed cheek is characteristic of *Ctenocephalus*, rather than *Conocoryphe*, as exemplified in *Ctenocephalus tumida* Grönwall (1902, p. 99), and its presence in this very early *Conocoryphe* may perhaps indicate a convergence of the *Conocoryphe* and *Ctenocephalus* stems.

Paradoxides parvoculus, new species

Pl. 3, Figs. 12, 13

Only the cranidium is known.

Cranidium of the ordinary Paradoxidian form. Glabella large, evenly rounded in front, and narrowed at the rear so that it is only $\frac{3}{4}$ as wide at the neck ring as it is at the widest part in front. The widest part of the glabella is $\frac{1}{3}$ of the way back from the front. At this widest point the glabella is a little more than half as wide as the cephalon is long. There are four glabellar furrows in addition to the neck furrow. The neck furrow is transverse and rather lightly impressed across the axis of the glabella, but is curved forward at an angle of 45 degrees and is deeply impressed at the sides. The second glabellar furrow is nearly transverse at the sides, but curves backward to form a shallow, backward-pointing arc over the axis. The third furrow is not continuous across the glabella, but is represented by two short furrows, extending in from each side about half the way to the median axis of the glabella, and about at right angles to that axis. The anterior, or fourth pair of glabellar furrows, which are situated opposite the anterior ends of the palpebral lobes and at the widest part of the glabella, are slightly shorter than the third pair and are deflected slightly forward from the outside toward the inside of the glabella. The neck ring of medium width, with a small tubercle. Fixed cheeks subtriangular, about $\frac{1}{6}$ longer than wide. Brim flat or perhaps with a slightly elevated rim on its front edge. The brim is narrow in front of the glabella, but widens toward each side. In the holotype, which is 22 mm. long, the brim is 1 mm. wide in front of the median axis of the glabella, and 4 mm. wide at the sides. The glabella is separated from the brim and from the fixed cheeks by a continuous furrow of medium width and depth. The posterior marginal furrow, running transversely across the rear ends of the fixed cheeks, is also of medium width and depth. The eyes are very short and

narrow. They are curved, and extend obliquely backward from a point close to the glabella at the glabella's widest part. They are only about half as long as the free cheeks, reaching back only to a point opposite the middle of the second glabellar furrow. They are very narrow, being slightly less than 1 mm. wide on the holotype cranium, which is 22 mm. long. The anterior branch of the facial suture is at an angle of about 45° with the median axis of the cranium; the posterior branch is straight, and is directed at an angle of about 25° from the median axis of the cephalon. The surface of the fixed cheeks is covered with many anastomosing raised lines, which form a fine and somewhat irregular wrinkled network. The rest of the cranium appears to be smooth or ornamented only with very fine concentric or parallel lines, and perhaps very fine tubercles.

Length of the holotype head, 22 mm.; width at rear, 16 mm.; length of eye lobe, 5 mm.; width of eye lobe, $1\frac{1}{2}$ mm.; length of posterior branch of facial suture (behind the palpebral lobe), 6 mm.

Horizon, beds 23 and 26, in the upper part of the benetti zone. Rare.

The holotype is specimen 8027 in the paleontological collections of Princeton University. It is from bed 23. A smaller head, whose exact horizon is unknown but which was found either in bed 23 or an adjacent bed, is number 8022. Both it and the holotype are figured. Another small head from bed 23, which seems to be referable to this species, is numbered 8028 (natural mould, 8041).

The specific name refers to the size of the eye lobes, which are unusually small for a *Paradoxides*.

Parvovulus has perhaps the smallest eye lobe of any known species of *Paradoxides*. It appears to be most closely related to *Paradoxides hicksi*, and may prove to be an ancestral variety of that species; but it seems best not to call it such until more is known of the ontogeny and phylogeny of *hicksi*. *Hicksi* appears to be a variable species, but some of the British forms assigned to it should perhaps be con-

sidered as varieties of the typical form. *Parvocus* differs from *hicksi* as described by Salter (1869, p. 55) in having narrower eye lobes, a shorter glabella that is more evenly rounded at the front, with the two rear glabella furrows extending all the way across the glabella in adult species, and a flat or nearly flat brim. It closely resembles one of the heads figured by Illing (1916, pl. XXXVI, fig. 3) as *P. hicksi*, differing only in the fact that, while the second glabellar furrow of Illing's specimen arches forward, that of *parvocus* bends backward. Illing's specimen came from a much higher horizon than *parvocus*, however (the upper part of the *hicksi* zone). In the general shape of the glabella and the thinness of the eye lobe, *parvocus* resembles young specimens of *hicksi* occurring in the *hicksi* zone at Manuels, and it seems probable, therefore, that it is the ancestor of *hicksi*, and that *hicksi* may have evolved in America. The flat or nearly flat brim of *parvocus* is also characteristic of early types of *Paradoxides*, as pointed out by Professor Raymond (1914, p. 235).

Liostracus globiceps jaculator, new variety

Pl. 3, Fig. 14

Only the cranium is known.

Cranidium moderately convex (in specimens preserved in shale), the glabella only a little more convex than the rest of the cephalon. The front of the cephalon is an arc of very slight curvature, and the facial suture runs so nearly straight back from this front edge to the palpebral lobe that the front half of the cranium has a rectangular appearance. Back of the palpebral lobe the facial suture runs diagonally backward and meets the posterior marginal furrow at an angle of about 45° . The brim is flat and broad, and is separated from the rest of the cephalon by a broad, shallow furrow. The fixed cheeks, which are moderately convex, join broadly in front of the glabella, the distance between the front of the glabella and the anterior marginal furrow being slightly more than half the distance between

the side of the glabella and the palpebral lobe. The fixed cheek is almost twice as wide at its posterior end as it is opposite the palpebral lobe, so that the cephalon is only $\frac{2}{3}$ as wide at the front as it is at the rear. The posterior marginal furrows are wide and shallow, as is the furrow that separates the glabella from the fixed cheeks. A facial ridge runs from near the front of the glabella outward and slightly backward, in a gentle curve, to the anterior end of the palpebral lobe. The neck ring is of medium size, and is prolonged backward into a spine, which is so long that the spine and neck ring combined are almost as long as the glabella. The glabella tapers slightly toward the front, where it is evenly rounded. It has four pairs of short, shallow, indistinct furrows which run obliquely backward at an angle of about 20° , from the outer edge of the glabella $\frac{1}{2}$ to $\frac{2}{3}$ of the distance toward the middle line of the glabella. The anterior pair of furrows are the shortest, the posterior the longest, the other two being intermediate in length. The anterior furrow starts from a point opposite the inner end of the facial ridge. The surface of the cranidium is covered with closely set tiny pits, not visible to the naked eye, and there are faint indications of parallel lines running across the part of the free cheeks in front of the facial ridge in a direction perpendicular to the facial ridge, such as are frequently found in other species of *Liostracus* and allied genera.

Length of largest cranidium referred to this form, 10 mm.; width at front of cephalon, 10 mm.; width at rear of cranidium, 15 mm.; length of glabella, 6 mm.; width of glabella at rear, 6 mm.

Horizon, beds 86 and 91, in the upper part of the hicksi zone. Rare.

The holotype is specimen 8023 in the paleontological collections of Princeton University. It is a small cranidium, being only 7 mm. in length, including the spine. It is chosen as the holotype because it is the only specimen now

in hand in which the spine is well shown. It is from bed 8C. Other specimens referred to this form are numbered 8034, 8035, and 8036. The measurements given above for the "largest cranidium" were taken from specimen 8035.

The specific name refers to the spine, which distinguishes the variety from *Liostracus globiceps*.

This form appears to be certainly a variety of *Liostracus globiceps* Grönwall (1902, pp. 145, 146, 218, pl. IV, figs. 12a, 12b). It seems to differ from that form only in the possession of a large neck spine. Grönwall describes and figures only a little spine on the neck ring of *globiceps*. Grönwall's cephalae seem to have been more convex than the specimens from Manuels, but, as the Manuels specimens are in shale, and probably somewhat flattened, it is not likely that the two forms differed in convexity in life. Grönwall records *globiceps* from Bornholm Island, Denmark, probably from the *dauidis* zone.

EXPLANATION OF PLATE 3

NEW TRILOBITES FROM THE CAMBRIAN PARADOXIDES' BEDS AT MANUELS, NEWFOUNDLAND

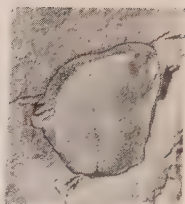
	PAGE
FIG. 1. <i>Agnostus claræ</i> , n. sp. Holotype pygidium. 4/1. Bed 23, in the upper part of the Paradoxides bennetti zone. Princeton catalog number 8000	74
FIG. 2. <i>Agnostus barlowi</i> Belt, var. <i>definitus</i> , n. var. Holotype pygidium. 4/1. Bed 23, in the upper part of the Paradoxides bennetti zone. Princeton catalog number 8001	76
FIG. 3. <i>Agnostus barlowi</i> Belt, var. <i>definitus</i> , n. var. Cranidium referred to this form. 4/1. Bed 23, in the upper part of the Paradoxides bennetti zone. Princeton catalog number 8003	76
FIG. 4. <i>Agnostus parvifrons</i> Linnarsson, var. <i>punctifer</i> , n. var. Holotype pygidium, top view. 4/1. Bed 101, in the lower part of the Paradoxides davidis zone. Princeton catalog number 8004	78
FIG. 5. <i>Agnostus parvifrons</i> Linnarsson, var. <i>punctifer</i> , n. var. Side view of the pygidium whose top view is shown in Fig. 4. 4/1	78
FIG. 6. <i>Agnostus vaningeni</i> , n. sp. Holotype pygidium. 4/1. Bed 99, in the lower part of the Paradoxides davidis zone. Princeton catalog number 8011	80
FIG. 7. <i>Agnostus longifrons</i> Nicholas, var. <i>parvulus</i> , n. var. Holotype cranidium. 4/1. Bed 109, in the middle part of the Paradoxides davidis zone. Princeton catalog number 8014	83
FIG. 8. <i>Agnostus longifrons</i> Nicholas, var. <i>parvulus</i> , n. var. Pygidium referred to this form. 4/1. Middle part of the Paradoxides davidis zone. Princeton catalog number 8017	83
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FIG. 10. <i>Conocoryphe bullata</i> , n. sp. Holotype cranidium. 3/2. Bed 19, in the middle part of the Paradoxides bennetti zone. Princeton catalog number 8021	87
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FIG. 13. <i>Paradoxides parvoculus</i> , n. sp. Cranidium. 1/1. Upper part of the Paradoxides bennetti zone. Princeton catalog number 8041	89
FIG. 14. <i>Liostracus globiceps</i> Grönwall, var. <i>jaculator</i> , n. var. Holotype cranidium. 2/1. Bed 86, in the upper part of the Paradoxides hicksi zone. Princeton catalog number 8023	91



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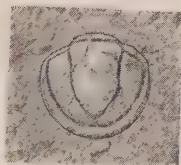
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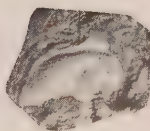
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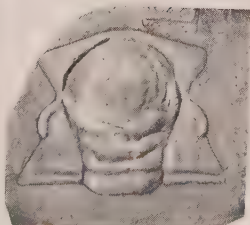
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VII. CORRELATION

Very few of the species of the Paradoxides faunas occur in any of the other known Cambrian faunas of the world; and none of those species are sufficiently diagnostic to enable us to use them with any confidence in close correlation. Therefore, although the Paradoxides beds and their fossils have been long known and much studied by geologists and paleontologists, and have proved so easy to correlate among themselves that it has been possible to make close comparisons of beds on opposite sides of the Atlantic, yet their exact age relationships with the other known faunas that are supposed to have existed in the world at about the same time are not well understood.

For many years after their discovery the Paradoxides faunas were considered to be the oldest well developed faunas known. They were spoken of as the "first fauna" or "primordial fauna." (Barrande, 1852; Murchison, 1872; Logan, 1866, in Murray and Howley, 1881, p. 49; Dawson, 1868, p. 638; etc.). Later when the term "Cambrian" came into general use, they were referred to as "Lower Cambrian" (Walcott, 1884). Finally, when in 1888, it was discovered that the "Olenellus" faunas really belonged below and not above them, the Paradoxides faunas were assigned to their present position in the Middle Cambrian (Walcott, 1888b).

In 1914 Professor vanIngen correlated the Paradoxides beds of Conception and Trinity bays, Newfoundland, including those at Manuels, with the "Acadian" division of the "St. John Group" of New Brunswick and the "Menevian and Solva" of Great Britain (vanIngen, 1914b). In the present unsettled condition of Cambrian nomenclature it seems wisest to refer to the beds of the Manuels series merely as "Cambrian Paradoxides beds," without using the qualifying "Middle." That the Paradoxides beds belong roughly in the middle, or what is now generally called the "Acadian," portion of what we now know as the Cambrian

is possible, but they cannot be correlated definitely with any part of the Cambrian of the southern, central, or western parts of North America, or of Asia or Australia, and the base and, more especially, the summit of the Cambrian system are at present so undefined, and may yet be so shifted, that it seems quite possible that the Paradoxides beds may at some time in the future be called something quite different from "Middle Cambrian." Indeed, Professor Charles Schuchert has proposed raising the "Middle Cambrian, Acadian, or Paradoxides epoch" to the rank of a period, the "Acadic Period" (Schuchert, 1910, pp. 520-522).

In his great work, "Revision of the Paleozoic Systems," Dr. E. O. Ulrich accepts the Middle Cambrian age of the Paradoxides beds, but objects to the assignment of the overlying "Olenus" beds to the Upper Cambrian, stating reasons for his belief that they were formed much later, probably in "Canadian" time (Ulrich, 1911, pp. 621, 678-680).

Whether the Paradoxides beds should be considered to include all of the Middle Cambrian of the Manuels Brook section is another question. The lowest of the overlying *Agnostus pisiformis* beds are certainly not Middle Cambrian in the sense in which that term is usually used today, and the same can be said of the underlying beds containing *Callavia broggeri*. The age of the black shales which intervene between the highest known Paradoxides beds and the lowest known *Agnostus pisiformis* horizon must remain in doubt until more is known about their fossils. The same is true of the beds lying between the lowest known Paradoxides beds and the highest beds in which *Catadoxides magnificus* has been found (see discussion of this question in Chapter IV, pp. 26, 27). The beds between the highest known *Callavia* horizon and the uppermost stratum in which *Catadoxides magnificus* is known to occur have been assigned to the Middle Cambrian by Dr. Walcott (1900a, pp. 315, 316; 1912, p. 140), and to the Lower Cambrian by Professor vanIngen (1914b).

The Paradoxides faunas are so distinctive and char-

Zones	Massachu- setts and ? Vermont	New Brunswick	Cape Breton	Manuels	Great Britain	Scandi- navia
Paradox- ides forch- hammeri zone			?	?		
Paradox- ides davidis zone						
Paradox- ides hicksi zone						
Paradox- ides bennetti zone						

TABLE V. Correlation of the Paradoxides faunas found at Manuels with those found in northwestern Europe and northeastern North America

acteristic that they are generally easy to recognize and correlate with each other. Salter (1859) and Jackson (1859a) compared the first specimens of Paradoxides discovered in Newfoundland (examples of *Paradoxides bennetti*) with *Paradoxides spinosus* of Bohemia and *Paradoxides harlani* of Massachusetts. Billings, who studied the collections made by the Geological Survey of Newfoundland, correlated the beds containing Paradoxides faunas there with "the Lower Lingula flags of Great Britain, or the Menevian Group of Salter and Hicks" (Billings, 1872, p. 470; 1874, p. 69); and Dawson (1873, p. 5) correlated them with the "Acadian Group" of New Brunswick, "the gold-bearing rocks of Nova Scotia," "the slates of Braintree in Massachusetts," and the "Menevian of Salter, Etage D of Barrande." In his report of the progress of the Newfoundland Survey for 1868, Murray referred the Paradoxides beds at Manuels to the "Lower Silurian," although he had found no fossils in them. Weston, who in 1874 made the first discovery of fossils at Manuels, correlated the beds containing them with the Paradoxides beds of New Brunswick on the evidence of the first specimen he found (Weston, 1898, p. 153). The New Brunswick beds had been correlated in 1865 by C. F. Hartt and Dr. G. F. Matthew with the Paradoxides beds of Massachusetts, the *Paradoxides bennetti* beds of St. Mary's Bay, Newfoundland, the Lingula flags of Great Britain, the "alum-schists" of Scandinavia, and "Etage C of Barrande in Bohemia" (Matt., 1865, p. 427). In 1878 Whiteaves also correlated the Manuels Paradoxides beds with the "St. John's group" of New Brunswick (Whiteaves, 1878). In 1881 Etheridge correlated the Menevian of Wales with "the St. John's group in Newfoundland" (Etheridge, 1881, p. 68). In 1884 Dr. C. D. Walcott (1884, p. 13) correlated these beds with the New Brunswick beds and with "the lower part of the Menevian, or possibly with portions of the Harlech and Longmynd group" of Great Britain. He pointed out the fact that the species then known to occur in the *Paradoxides harlani* beds of Braintree, Massachu-

setts, all appeared to be represented by very similar forms in Newfoundland (1884, p. 44). None of the Newfoundland species that he mentioned as comparable with the Braintree forms were then known to occur at Manuels, but most, or all, of them have since been found there.

In 1885 Dr. Matthew stated that the fossils then known from the Paradoxides beds of Manuels Brook appeared to be of early Paradoxidian age, like those of the "Acadian" of St. John, New Brunswick, and the Solva of Great Britain (Matthew, 1885, pp. 121 and footnote, and 122). In the following year he referred the Manuels fossils to the "Horizon of the Conocoryphinae," the lowest Paradoxides horizon then known in Newfoundland (Matthew, 1886, p. 149); and two years later he correlated the "Shales of Manuel R." with "Division" 1c of the "St. John Group" of Canada, the upper part of the "Upper Sparagmite formation=Etage 1b and c" of Norway, the upper part of the "Lower Paradoxides Beds" of Sweden, and doubtfully with the upper part of the "Solva group" of Great Britain (Matthew, 1888a, p. 25).

In 1888 and 1891 Dr. Walcott (1888b, p. 551; 1889a, pp. 383, 386; 1891a, pp. 582, 583; 1891b, pp. 66, 360; 1891c) correlated the Paradoxides beds at Manuels with those of New Brunswick, Massachusetts, and Great Britain.

In 1890 Dr. Matthew (1890, p. 137) correlated the upper Paradoxides beds at Manuels with the Menevian of Wales, "Etage 1d" of Norway, and the "Upper Paradoxides Beds" of Sweden; and the two lower "zones" of the Paradoxides beds at Manuels with the "Lower Paradoxides Beds" of Sweden, a part of the "Upper Sparagmite-Etage 1c" of Norway, and a part of the Solva of Great Britain. In the following year he correlated the Newfoundland faunas with those in other parts of the world, as shown in table II (page 15 of the present paper). In 1896 he divided them into the following subzones:

3. "Subzone of *P. davidis*."

2. "Subzone of *P. abenacus*" (doubtfully identified in Newfoundland).

1. "Subzone of *P. etemnicus*."

and correlated these subzones with what he considered to be their equivalents in Massachusetts, New Brunswick, France, Spain, Bohemia, Sweden, Norway, and Wales (Matthew, 1896, pp. 193, 194).

In 1897 Frech correlated the "Zone mit *P. Davidis* und *Ptych. Linnarsoni* Brögg." at Manuels with the "Middle Menevian mit *Par. davidis*" of Wales, the zone of "*Par. Davidis* (*Microdiscus* u. *Par. Tessini*)" of Sweden, and the "*Schiefer m. Par. rugulosus*, *Con. Sulzeri*, *Agnostus nudus*" of Norway; and correlated the "*Schichten mit Paradoxides Hicksi*" at Manuels with the "*Lower Menevian mit Par. Hicksi und aurora*" of Wales, the zone of "*Par. Tessini* (u. *Par. Hicksi*, *Ellips. granulatus*, *Conoc. exsulans*, *Ptych. Linnarssoni*, *Agnostus rex*)" of Sweden, the "*Schiefer mit Par. Tessini*" of Norway, and the "*Sandstein mit Par. Tessini*" of Sandomir, Poland (Frech, 1897, pp. 34-38).

In 1899 Dr. Matthew (1899c, p. 67) subdivided the *Paradoxides* beds of Newfoundland and correlated them with beds in New Brunswick, as shown below (the notes in parenthesis refer to New Brunswick):

Horizon of *Paradoxides davidis* (unknown in New Brunswick).

Horizon of *Paradoxides tessini* (=subzone of *Paradoxides abenacus*).

Horizon of *Paradoxides spinosus* (=subzone of *Paradoxides etemnicus*).

Horizon of the *Conocoryphinae* (=subzone of *Paradoxides etemnicus*).

In 1914 Professor vanIngen correlated the Manuels series with the "Acadian" of "N. E. America" and the Menevian and Solva of "Western Europe," as mentioned above (vanIngen, 1914). A more detailed correlation table, drawn up by the writer, is shown in table V .

As far as can be told at the present time, the *Paradoxides* faunas of southeastern Newfoundland are more nearly related to those of New Brunswick, Massachusetts, Great Britain and Scandinavia, than to those of France, Bohemia, Poland and southern Europe. The fossils of the *Paradoxides* beds of Vermont will probably also prove to be closely related to those of Newfoundland, but they are at present too little known to make a satisfactory comparison possible (see page 106).

The succession of early Paleozoic faunas in southeastern Newfoundland, from the Lower Cambrian to the Lower Ordovician, appears to have been very much the same as it was in Massachusetts, New Brunswick, Great Britain, and Scandinavia, as is shown in table VII (p. 101). Recent discoveries in Shropshire and Warwickshire, England, also indicate the presence there of "*Callavia*" and "*Protolenus*" faunas very similar to those of southeastern Newfoundland (Cobbold, 1910; 1919; 1921; Illing, 1913; 1914a, 1916).

One of the most interesting things about the *Paradoxides* fossils at Manuels is their very close resemblance to the contemporary fossils of Europe, in general, and of Great Britain, in particular. The number of identical or nearly identical species found at Manuels and in Europe, and the similarity of their ranges on the two sides of the Atlantic, are illustrated in table VI and on pages 117-132. What we know of the species occurring above and below the *Paradoxides* beds at Manuels, including those found in the beds of Kelly's, Little Bell, and Great Bell Islands, in Conception Bay, indicates that they, too, are closely related to forms of the same age in Europe. Altogether, they and the fossils of the *Paradoxides* beds exhibit one of the most interesting examples known of a succession of very similar faunas on opposite sides of the Atlantic Ocean.

The *Paradoxides* faunas of Scandinavia seem also to be very similar to those of Manuels, but they do not seem to show quite so close a resemblance as do those of Great Britain. They are compared on pages 125-132. Interesting

SOUTHEASTERN NEWFOUNDLAND	MASSACHUSETTS	NEW BRUNSWICK	GREAT BRITAIN	SCANDINAVIA
"Arenig" faunas, with Ditymograptus, etc.		Fauna or faunas characterized by Ditymograptus and Tetra- graptus (C & d).	Arenig faunas, with Dity- mograptus, Tetragraptus, etc.	"Arenig" faunas, with Dity- mograptus, Tetragraptus, etc.
"Tremadoc" faunas, with Niobe, Parabolina, Shumardia, Bryo- graptus, and Orusia lenticularis.	+	Faunas characterized by Ctenopryge, Parabolina, Bryo- graptus, and Dictyonema (C Sa-c).	Tremadoc and Upper Lingula Facies faunas, with Niobe, Shumardia, Bryograptus, Parab- olina, and Orusia lenticular- is.	"Tremadoc" faunas, with Ceratopryge, Shumardia, Parabolina, and "Dityograptus" (Dictyonema).
Fauna characterized by Agnostus pisiformis obesus and species of Olenus.	+	(Probably represented in part, at least, by the fauna or faunas character- ized by Acantholenus and varieties of Agnostus pisiformis (C2).	Fauna characterized by Ag- nostus pisiformis obesus and species of Olenus.	Fauna characterized by Agnos- tus pisiformis obesus and species of Olenus.
Aagnostus pisiformis.	+		(Known to be lacking in the sections in some districts in Great Britain, but part (particularly some of the Paradoxides forchhammeri fauna) may prove to be present in other districts.	Aagnostus pisiformis.
Aagnostus laevigatus?	+	Not known to be present.		Aagnostus laevigatus.
Paradoxides forchhammeri fauna?	+	Not certainly known to be present. Possibly represented in Cape Breton.		Paradoxides forchhammeri fauna.
Paradoxides davidis fauna.	+	Not certainly known to be present.	Paradoxides davidis fauna.	Paradoxides davidis fauna.
Paradoxides hickni fauna.	+	Paradoxides abeneus fauna (C1d).	Paradoxides hickni fauna.	Paradoxides hickni fauna.
Paradoxides bennetti fauna.	+	Paradoxides regina fauna, with P. lamellatus and P. stemmatus (C1c1,2).	Paradoxides grooni fauna.	Paradoxides glandicus fauna.
Catadoxides fauna.	+	Not known to be present.	Not known to be present. Pos- sibly represented in the "black limestone" of Comley Quarry, Shropshire.	Not known to be present.
Protolenus fauna.	+	Protolenus fauna.	Protolenus fauna.	Not known to be present
Callavia fauna.	+	Callavia fauna.	Callavia fauna.	Fauna or faunas characterized by Holmia and Mesonacis.

Table VII. Table to show the similarity in the succession of Cambrian, Ozarkian, and Lower Ordovician faunas in southeastern Newfoundland, Massachusetts, New Brunswick, Great Britain, and Scandinavia.

correlations might also be made between the Manuels faunas and those of Bohemia, Poland, France, and the Iberian Peninsula; but, as they can be made with much greater accuracy after the Paradoxides faunas of all of southeastern Newfoundland have been more thoroughly studied, they are not attempted in this paper.

The great similarity between the Paradoxides faunas of North America and Europe naturally raises the question of migration between the two regions. Did any or all of the faunas originate in one of these regions and migrate to the other; or did they come in from some outside source? If they came from outside, did they occupy one of the two regions for any appreciable period before advancing to the other; or did they invade both regions quite, or nearly quite, simultaneously? These are difficult questions, most of which probably cannot be satisfactorily answered with the information now at hand. In the regions where the Paradoxides faunas and those which preceded them have been most carefully and thoroughly studied, none has been found which can be said to have been the immediate ancestor of the earliest known Paradoxides assemblage. This indicates either that the first known Paradoxides faunas entered those regions from outside, or that, if they evolved in those regions, conditions at the time of their evolution and since have destroyed all records of their earlier stages. There are unconformities between the Paradoxides beds and the beds underlying them in some regions, but there is certainly no angular unconformity at the bottom of the Paradoxides beds at Manuels, and, as has been stated before, it is doubtful whether there is any well marked disconformity present.

The first Paradoxides faunas seem to have come in with an advancing sea in most of the regions in which they have been found, and appear to have been followed by successive invasions of later and slightly different forms; for while the changes from one fauna to the next succeeding one are usually gradual, in the sense that old species slowly drop out as new ones come in and that some stems gradually

change in character, nevertheless, many entirely new types enter which could have had no antecedents in this region; so that there must certainly have been open an outside source of new life during most of known Paradoxidian time.

In almost every section where any two of the three sets of faunas, the "Olenellus," "Paradoxides," and "Olenus," have been reported in the regions where Paradoxides is known to occur (Europe and northeastern North America) there are present either the "Olenellus" and "Paradoxides," "Olenellus," "Paradoxides" and "Olenus," or "Paradoxides" and "Olenus" faunas—very seldom the "Olenellus" and "Olenus" faunas together without the "Paradoxides."

Probably the following tentative deductions are the ones which can most logically be drawn from the facts now at hand:

1. No fauna immediately ancestral to the earliest known Paradoxides faunas has been found. The nearest ancestral faunas now known are probably those characterized by Catadoxides in southeastern Newfoundland and by Metadoxides in Sardinia.
2. The earliest known Paradoxides faunas probably invaded the regions where their remains are now found from some outside area, and the new types which distinguish the succeeding faunas also came in from the same or some other outside place or places, those after the earliest one being composed of a combination of these new types and survivals and derivatives of the fauna or faunas which preceded them. Some or all of the ancestors of the Paradoxides faunas may have developed in the regions where Paradoxides is now found, but, if they did, no record of their presence there has been discovered.
3. The migrations of the Paradoxides faunas over the European and northeastern North American

regions appear to have been mainly in the nature of direct invasions from some outside region.

4. There is a great faunal break between the latest Paradoxides fauna and the next succeeding well-developed one at every known place where they occur.

The similarities and differences between the Paradoxides faunas found at Manuels and other regions are roughly indicated in tables IV and V, and are briefly described under separate headings in the remaining part of this chapter.

COMPARISON OF THE PARADOXIDES FAUNAS OF MANUELS WITH THOSE OF BRAINTREE, MASS.

The Braintree fauna and the fauna of the lower 21 feet and 7 inches (beds 1-13) of the bennetti zone at Manuels, so far as they are known at the present time, are essentially alike. The two faunas are listed below, species which are known to be identical or very similar being placed opposite each other. The Braintree list is taken partly from Walcott (1884) and Grabau (1900). The Manuels list, like all the other lists of fossils from Manuels in this chapter, includes only species which the author has found at that locality. The numbers in parenthesis following the names of the species in the Manuels list indicate the particular beds of the lower 21 feet and 7 inches of the bennetti zone in which each species has been found.

LOWER PARADOXIDES BENNETTI FAUNA AT
MANUELS

Paradoxides bennetti Salter (2?, 3?, 5?, 6-8, 10?, 13)
 Ptychoparia rogersi (Walcott) (8)
 Agrauios cf. affinis Billings (8)
 Agrauios cf. rex (Barrande) (8)
 Acrothele cf. matthewi (Hartt) (3, 16)
 Lingulella ferruginea Salter (3, 10)
 Hyolithid gen. & spec. undet. (1, 4?)
 Hyolithid gen. and spec. undet., different from the
 one found in bed 1? (10)

Sponge gen. and sp. undet. (1)

It would seem that faunas so nearly the same as these
 two must certainly be of almost or exactly the same age.

PARADOXIDES HARLANI FAUNA AT
BRAINTREE

Paradoxides harlani Green
 Paradoxides haywardi Raymond
 Ptychoparia rogersi (Walcott)
 Agrauios quadrangularis (Whitfield)
 Agnostus cf. rex (Barrande)
 Acrothele gamagei (Hobbs)

Hyolithes shaleri Walcott
 Hyolithes (?) haywardensis Grabau

It appears to be quite within the realms of possibility that true *Paradoxides harlani* occurs in the *bennetti* beds of Newfoundland, and that some or all of the known specimens of *bennetti* are to be referred to *harlani*, or that *bennetti* is to be considered a variety of *harlani*. These possibilities have been considered by Jackson (1859a, 1859b), Rogers (1859), and Dr. Walcott (1884, p. 44). The question cannot be answered properly until an examination has been made of the type specimen or specimens of *bennetti*, which are in England. It will be dealt with further in a future paper, in which the *bennetti* and *harlani* faunas will be compared in detail. *Paradoxides regina* Matthew, of New Brunswick, is also closely related to *harlani* and *bennetti*, as pointed out by Matthew (1888c, pp. 122, 123) and Grabau (1900, pp. 687-689). *Paradoxides groomi* Lapworth (1891, p. 532, footnote) appears to be another very similar form.

Whatever may be the relations of *bennetti* to *harlani*, the recognition of a *bennetti* fauna in the lower part of the Manuels Brook *Paradoxides* section and the close resemblance of the lower "bennetti" sub-fauna to the *harlani* fauna make it possible for us to place the two definitely in their proper part of the North American *Paradoxides* section. If the "bennetti" of this lower sub-fauna proves to be a distinct form, we shall be able to separate the lower sub-fauna as the "harlani" sub-fauna or fauna.

Dr. Matthew (1887, p. 149) placed his "Horizon of *P. spinosus*" (the lower *bennetti* zone of the present paper) above the "Horizon of the *Conocoryphinae*" (the upper *bennetti* zone of this paper) in his classification of the *Paradoxides* beds of Newfoundland; and Jules Marcou (1889, pp. 122, 123; 1890a, pp. 357, 368, 369; 1890b, pp. 83, 84), apparently on the strength of unpublished information furnished to him by Mr. Howley, stated that the *Paradoxides bennetti* beds were probably the oldest *Paradoxides* beds

known in Newfoundland; but he was not certain about the matter, and presented no satisfactory evidence in support of his views; and it was not until the bennetti fauna was recognized in the Manuels section that its exact stratigraphic position became known.

The presence at Braintree of an agnostid resembling *Agnostus rex* has not been previously recorded. A head of the rex type was found in Hayward's quarry in that town by Professor P. E. Raymond and the writer in 1918. It is specimen 8042 in the paleontological collections of Princeton University. The counterpart of the head is in the Museum of Comparative Zoology at Cambridge.

The species *Parmophorella acadia* (Hartt), which was recorded from Braintree by Grabau (1900, pp. 625, 626), has not been included in the list of species found in the Paradoxides beds of Massachusetts because, after a comparison of the very fragmentary specimen on which Dr. Grabau's identification was based with examples of *Acrothele gamagei* and with the type specimen of *Parmophorella acadia*, the writer believes that Dr. Grabau's fossil is a valve of *Acrothele gamagei*, and almost certainly not a *Parmophorella*.

It is an interesting fact that the shale holding the *Paradoxides harlani* fauna at Braintree is a hard, heavy-bedded, brown-weathering, gray rock, which seems to be very similar to the gray shales of the lower part of the bennetti zone at Manuels, except that it is harder and more heavily bedded.

COMPARISON OF THE PARADOXIDES FAUNAS OF MANUELS WITH THE PARADOXIDES FAUNA OF VERMONT

Very little has been published about the *Paradoxides* fauna of Vermont. Between 1886 and 1905 Dr. Walcott recorded the finding of a few fossils which may prove to

belong to this fauna (Walcott, 1887, p. 17; 1891b, p. 310; 1898, pp. 404, 405; 1905, pp. 291, 292). In 1908 Dr. G. H. Perkins reported that some fossils collected by Mr. G. E. Edson of St. Albans had been referred by Dr. Walcott to the genera "*Obolus*, *Lingulella*, *Hyolithes*, *Leperditia*, *Agnostus* (two species), *Agraulos*, *Menocephalus*, *Ptychoparia* (three species), *Anomocare*, *Paradoxides*" (Perkins, 1908, pp. 208, 209). In 1910 Dr. Walcott identified the *Paradoxides* as *Paradoxides harlani* Green (Walcott, 1910, p. 254); and in 1912 he recorded two species of brachiopods, "*Obolus matinalis*?" and "*Huenella vermontana*," from the beds holding this *Paradoxides*, and described and figured two species of brachiopods (*Lingulella franklinensis* and *Huenella billingsi*) and recorded one species of trilobite (*Ptychoparia adamsi*) from beds in the same general region which he thought might be of "Middle Cambrian" age (Walcott, 1912).

In the summer of 1922 the writer examined the beds in which Mr. Edson had found his fossils and other similar beds in northwestern Vermont which appeared to be of the same age, and collected several hundred fossils from them. The beds consist of dark shales and peculiar conglomerates whose "pebbles," which are frequently sharply angular, are of all sizes from blocks many tons in weight to pieces no larger than a pea, and whose martrix is sometimes sand, sometimes shale, sometimes limestone, and sometimes a mixture of two or all of those materials. Fossils were found only in the dark shales and the "pebbles" of the conglomerate. Most of them are trilobites, but there are also a few brachiopods. They are evidently Cambrian, but whether they are all of Paradoxidian age has not yet been determined. One fragmentary trilobite cranium was found that may be referable to *Paradoxides harlani* (specimen 8043 in the Princeton paleontological collections), and several other fragments that are probably *Paradoxides* were collected. Some of the other specimens collected may also prove to be referable to species that are associated with

Paradoxides elsewhere than in Vermont. But the assemblage, as a whole, is not like any of the Paradoxides faunas that have been described from any other region. The writer plans to make a more detailed study of these beds in the summer of 1925, in the hope of being able to learn more about their fossils.

*COMPARISON OF THE PARADOXIDES FAUNAS OF
THE MANUELS BROOK SECTION WITH THOSE
OF NEW BRUNSWICK AND CAPE BRETON*

Dr. Matthew has divided the Paradoxides beds of New Brunswick and Cape Breton into five zones, which he has designated as follows, from the highest downward (189^p p. 259) :

- C2 —Gray quartzites, flags and slates (Upper Paradoxides fauna).
- C1d2—Dark gray shales and limestone lentils (Dorypyge sub-fauna).
- C1d1—Dark gray shales (Paradoxides abenacus sub-fauna).
- C1c2—Gray shales (Paradoxides eteminicus sub-fauna).
- C1c1—Gray shales (Paradoxides lamellatus sub-fauna).

The highest of these zones has been recognized only in Cape Breton. It appears to be correlatable with the "Paradoxides forchhammeri" zone of Scandinavia, which is not known to be represented in Newfoundland. The other four zones are probably included, in whole or in part, in the bennetti, hicksi, and possibly the lowest part of the davidis, zones of the Manuels Brook section. The "lamellatus" and "eteminicus" zones are well developed only in New Brunswick. They appear to be correlatable with the bennetti beds at Manuels, but their fossils do not seem to be clearly distinguishable as two separate faunas there.

The trilobites and brachiopods of the faunas recorded by Dr. Matthew and by Dr. Walcott from the "lamellatus and "eteminicus" zones are compared below with the trilobites and brachiopods of the bennetti fauna of the Manuels Brook section, so far as that fauna is now known. Identical and similar species are placed opposite each other in the two lists. The horizon of each species in New Brunswick is indicated as it is recorded by Dr. Matthew (1893, pp. 113-119; 1904) "C1c1" indicating the "lamellatus" zone, "C1c2" the "eteminicus" zone, and "C1c" either one or both of the two. The numbers following the names of the Newfoundland species refer to the beds of the Manuels Brook section, as they are numbered in the present paper (pp. 43-93). This and the other New Brunswick lists of the present chapter are made up from information contained in Dr. Matthew's papers and Dr. Walcott's monograph, "Cambrian Brachiopoda" (Walcott, 1912).

SPECIES FOUND IN THE BENNETTI ZONE
AT MANUELS

(The numbers in parentheses indicate the beds in which each species has been found.)

Trilobites

Paradoxides bennetti Salter (2?, 3?, 5?, 6-8, 10?, 13, 19, 22-24, 26-32, 33?, 34?, 35?)
Paradoxides lamellatus Hartt (21)

Paradoxides eteminicus Matthew (19, 21-35)

Paradoxides parvoculus, n. sp. (23, 26)

Bailiella baileyi (Hartt) (23, 25, 29, 31-35)

Conocoryphe elegans (Hartt) (23, 25-29, 31, 34)

Conocoryphe bullata, n. sp. (19)

Harttella matthewi (Hartt) (21-23, 25-29, 32, 34, 35)

Liostracus ouangondianus (Hartt) (23, 26, 28, 29, 31)

SPECIES FOUND IN THE LAMELLATUS AND
ETEMINICUS SUBZONES OF NEW
BRUNSWICK

Trilobites

C1c2 *Paradoxides regina* Matthew

C1c1 *Paradoxides lamellatus* Hartt

C1c2 *Paradoxides lamellatus* loricatus Matthew

C1c2 *Paradoxides eteminicus* Matthew

C1c2 *Paradoxides eteminicus brevius* Matthew

C1c2 *Paradoxides eteminicus malicetus* Matthew

C1c2 *Paradoxides eteminicus quacensis* Matthew

C1c2 *Paradoxides eteminicus suricoides* Matthew

C1c2 *Paradoxides acadicus* Matthew

C1c2 *Paradoxides acadicus suricus* Matthew

C1c2 *Paradoxides micmac* Hartt

C1c1 *Paradoxides micmac pontificalis* Matthew

C1c1 *Bailiella walcotti* (Matthew)

C1c2 *Bailiella baileyi* (Hartt)

C1c2 *Bailiella baileyi arcuata* Matthew

C1c2 *Conocoryphe elegans* (Hartt)

C1c2 *Conocoryphe elegans granulata* Matthew

C1c2 *Harttella matthewi* (Hartt)

C1c2 *Harttella matthewi hispidus* Matthew

C1c2 *Harttella matthewi geminispinosus* Matthew

C1c1 *Harttella matthewi perhispidus* Matthew

C1c1 *Liostracus ouangondianus* (Hartt)

- Liostracus* cf. *ouangondianus* (Hartt) (15, 17, 19, 21)
 C1c1 *Liostracus ouangondianus* gibba Matthew
 C1c1 *Liostracus ouangondianus* plana Matthew
 C1c2 *Liostracus ouangondianus* aurora Matthew
 C1c2 *Liostracus ouangondianus* emarginata Matthew
Liostracus tener (Hartt) (25-35)
 C1c1 *Liostracus tener* (Hartt)
 C1c2 *Liostracus tener* acuminata Matthew
Agraulos cf. *affinis* Billings (8)
 C1c1 *Agraulos* (?) whitfieldianus Matthew
 C1c2 *Agraulos* halliana Matthew
 C1c2 *Agraulos* (?) holocephalus Matthew
 C1c2 *Agraulos* (?) nannus Matthew
 C1c2 *Agraulos* (?) pusillus Matthew
 C1c2 *Agraulos* roberti Matthew
Ptychoparia cf. *rogersi* (Walcott) (8)
 C1c2 *Solenopleura robbi* (Hartt)
 C1c2 *Solenopleura robbi* orestes (Hartt)
 C1c2 *Eodiscus precursor* (Matthew)
 C1c1 *Goniodiscus dawsoni* (Hartt)
 C1c1 *Agnostus fallax trilobatus* Matthew (8, 23, 26, 28, 29, 31)
 C1c1 *Agnostus fallax* vir Matthew
 C1c1 *Agnostus gibbus* Linnarsson
 C1c1 *Agnostus regulus* Matthew
 C1c2 *Agnostus acadicus* Hartt
Agnostus granulatus (Barrande) (23, 28, 29)
Agnostus cf. *rex* (Barrande) (8, 19, 23, 25, 26, 28, 29, 31)
Agnostus cf. *exaratus* tenuis Illing (26)
Agnostus barlowi definitus, n. var. (23, 26, 28)
Agnostus clarae, n. sp. (23)

Brachiopods

Lingulella ferruginea Salter (3, 10, 19, 21, 23, 26, C1c1 & 2 Lingulella ferruginea Salter 28-35)

Acrothele matthewi (Hartt) (3?, 10?, 23, 26, 28-35) C1c Acrothele matthewi (Hartt)

C1c Acrothele matthewi lata Matthew

C1c Acrothele matthewi multicostata Matthew

Acrotreta gemmula Matthew (29)

Acrotreta cf. gemmula Matthew (21, 28)

C1c Acrotreta sagittalis magna (Matthew)

C1c Acrotreta sagittalis transversa (Hartt)

C1c1 Discinopsis gulleim! (Matthew)

Micromitra (Iphidella) cf. ornatella Linnarsson (21)

C1c1 & 2 Protorthis billingsi (Hartt)

C1c2 Prothorthis latourensis (Matthew)

C1c2 Prothorthis quacensis (Matthew)

C1c Eorthis hastingensis (Walcott)

Eorthis cf. papias (Walcott) (22)

Brachiopods

The trilobites and brachiopods of the faunas recorded by Dr. Matthew and Dr. Walcott from the "Paradoxides abenacus" and "Dorypyge" zones of New Brunswick are compared below with the known trilobites and brachiopods of the faunas of the hicksi zone of the Manuels Brook section. The presence in the "Dorypyge" zone of "Agnostus punctuosus var." may indicate that some of that zone may lap over from hicksi into davidis time, as punctuosus is not known below the davidis zone at Manuels. The apparent absence of Paradoxides hicksi from New Brunswick is very remarkable, and appears to indicate that a part of the hicksi zone is lacking there. The horizons are indicated as in the former list. "C1d1" is the "Paradoxides abenacus" zone; "C1d2," the "Dorypyge" zone. Where "C1d" is used it indicates that Dr. Matthew has not stated in which of the two zones the species occurs.

SPECIES FOUND IN THE PARADOXIDES ABENACUS AND DORYPYGE SUB-ZONES OF NEW BRUNSWICK

Trilobites

C1d Paradoxides abenacus Matthew

SPECIES THAT HAVE BEEN RECOGNIZED IN THE HICKSI ZONE AT MANUELS

Trilobites

Paradoxides bennetti Salter ? (41)
 Paradoxides cf. abenacus Matthew (51, 52)
 Paradoxides cf. eteminius Matthew (49)
 Paradoxides hicksi Salter (37, 40, 41, 43-46, 49, 51-58, 61, 62, 64-67, 70, 73-75, 77, 78, 80-90)
 Centroleura venusta Billings (86)
 Bailiella venulosa (Salter) (88)
 Conocoryphe elegans (Hartt) (40, 41)
 Conocoryphe æqualis Linnarsson (67, 79, 83, 84, 86, 87)

Liostracus tener (Hartt) (38-40)

Liostracus globiceps jaculator, n. var. (86, 91)

Agraulos socialis Billings (37, 40, 41, 43-46, 49-58, 61, 62, 64-67, 69-77, 80-84, 86, 87)

Solenopleura cf. applanata (Salter) (48, 55, 57, 67, 69, 77, 80, 83-86, 88, 91)

C1d Conocoryphe pustulosa Matthew

C1d Liostracus tener lævis Matthew

C1d Liostracus validus Matthew

C1d2 Liostracus ouangondianus (Hartt) var.

C1d2 Agraulos ceticephalus carinatus Matthew

C1d Agraulos socialis Billings

C1d Solenopleura acadica Whiteaves

C1d Solenopleura acadica elongata Matthew

C1d Solenopleura robbi parva Matthew

C1d Solenopleura arenosa Billings

C1d Ptychoparia adamsi Billings

C1d Ptychoparia limbata Matthew

- C1d Ptychoparia linnarssoni Brögger
 C1d Ptychoparia linnarssoni alata Matthew
 C1d2 Anomocari magnum Brögger var.
 C1d Dolichometopus acadicus Matthew
 C1d Dorypyge horrida Matthew
 C1d Dorypyge quadriceps valida Matthew
 C1d Dorypyge wasatchensis acadica Matthew
 C1d Eodiscus pulchella (Hartt)

 C1d1 Agnostus umbo Matthew
 C1d1 Agnostus rex transectus Matthew
 C1d1 Agnostus obtusilobus Matthew
 C1d1 Agnostus nathorsti Brögger
 C1d1 Agnostus nathorsti confuens Matthew

 C1d1 Agnostus gibbus acutilobus Matthew
 C1d1 Agnostus gibbus partitus Matthew
 C1d1 Agnostus fissus Lundgren MS

 C1d1 Agnostus fissus trifissus Matthew
 C1d1 Agnostus fallax Linnarsson ?

 C1d1 Agnostus fallax concinnus Matthew
 C1d1 Agnostus acadicus declivis Matthew

 C1d1 & 2 Agnostus parvifrons Linnarsson
 C1d2 Agnostus cf. parvifrons nepos Brögger
 C1d2 Agnostus parvifrons tessella Matthew

 C1d2 Agnostus parvifrons truncata Matthew
 C1d2 Agnostus punctuosus Angelin var.
- Eodiscus punctatus (Salter) (40, 44, 51, 52, 54, 67, 69, 75, 81, 83, 84, 86)
 Agnostus cf. umbo Matthew (90, 91)

 Agnostus cf. sulcatus Illing (90, 91)
 Agnostus cf. gibbus Linnarsson (88, 90)
 Agnostus cf. gibbus hybrida Brögger (48)

 Agnostus fissus Lundgren MS (41, 51, 57, 58, 64, 69, 72, 74, 77, 78, 81, 84, 85, 87-91)
 Agnostus cf. fallax Linnarsson (43, 45, 52, 64, 65, 81, 84, 86-91)

 Agnostus cf. acadicus declivis Matthew (40, 41, 43, 44, 48, 51-57, 70, 71, 74, 76, 77, 81, 84, 88, 92)
 Agnostus cf. parvifrons Linnarsson (90, 91)

 Agnostus cf. parvifrons tessella Matthew (48, 50, 80)

 Agnostus barrandei Salter (41, 43, 47, 48, 51, 55, 57, 58, 64, 65, 70, 77, 80, 81)
 Agnostus granulatus (Barrande) (43, 46, 51, 74, 80, 88, 90, 91)
 Agnostus rex (Barrande) (43, 44, 46, 52, 57, 65, 79, 88)

Agnostus cf. *nudus* (Beyrich) (44, 45, 69, 70)
Agnostus *laevigatus* *ciceroides* Matthew (81, 84,
 87-91)
Agnostus *laevigatus* *terranovicus* Matthew (90)

Brachiopods

Lingulella *ferruginea* Salter (37-41, 74)
Acrothele cf. *matthewi* (Hartt) (81)

Acrotreta *misera* (Billings) (48, 88, 90-92)

Brachiopods

Lingulella *ferruginea* Salter C1d
Acrothele *matthewi* (Hartt) C1d
Acrothele *matthewi* *lata* Matthew C1d
Acrothele *matthewi* *multicostata* Matthew C1d
Acrothele *prima costata* (Matthew) C1d
Acrotreta *baileyi* Matthew C1d
Acrotreta *gracia* Walcott C1d
Acrotreta *misera* (Billings) C1d
Acrotreta *sagittalis* (Salter) C1d
Acrotreta *sagittalis magna* (Matthew) C1d
Billingsella *coloradensis* (Shumard) C1d
Eoorthis *hastingsensis* (Walcott) C1d

*COMPARISON OF THE PARADOXIDES FAUNAS OF
THE MANUELS BROOK SECTION WITH THOSE
OF GREAT BRITAIN*

The Paradoxides faunas of Great Britain are very remarkably similar to those of Manuels. In Great Britain, as at Manuels, they can be divided into bennetti, hicksi, and davidis faunas. The trilobites and brachiopods of the faunas of the two regions are compared below. Identical and similar species are placed opposite each other in the two lists, as is done in the case of the other lists in this chapter. The lists of British species are probably not complete, but they are believed to include most, if not all, of the British forms that are identical with or very similar to the known Manuels species. Some of the British species may have been assigned to the wrong zones. It is sometimes difficult to decide whether a given form recorded in the literature has come from the hicksi or the davidis zone.

SPECIES FOUND IN THE PARADOXIDES
BENNETTI ZONE AT MANUELS

Trilobites

- Paradoxides parvculus, n. sp.
 Paradoxides eteminius Matthew
 Paradoxides lamellatus Hart
 Paradoxides bennetti Salter
 Conocoryphe bullata, n. sp.
 Conocoryphe elegans (Hartt)
 Bailiella cf. baileyi (Hartt)
 Harttella matthewi (Hartt)
 Liostracus tener (Hartt)
 Liostracus ouangondianus (Hartt)
 Ptychoparia cf. rogersi (Walcott)
 Agrauios cf. affinis Billings
 Goniodiscus dawsoni (Hartt)
 Agnostus cf. fallax trilobatus Matthew
 Agnostus granulatus (Barrande)
 Agnostus cf. exaratus tenuis Illing
 Agnostus cf. rex (Barrande)
 Agnostus claræ, n. sp.
 Agnostus barlowi definitus, n. var.

SPECIES FOUND IN THE PARADOXIDES
BENNETTI ZONE OF GREAT BRITAIN

Trilobites

- Paradoxides hicksi Salter
 Paradoxides aurora Salter
 Paradoxides harknessi Hicks
 Paradoxides sjogreni Linnarsson
 Paradoxides grommi Lapworth
 Plutonia sedwgicki Hicks
 Conocoryphe bufo Hicks
 Conocoryphe viola Woodward
 Conocoryphe lyelli Hicks
 Conocoryphe emarginata longifrons Cobbold
 Harttella solvensis Hicks
 Dorypyge lakei Cobbold
 Goniodiscus sculptus (Hicks)
 Agnostus sulcatus Illing
 Agnostus cf. intermedius Tullberg
 Agnostus lobatus Illing
 Agnostus granulatus (Barrande)
 Agnostus exaratus tenuis Illing
 Agnostus rex (Barrande)
 Agnostus barrandei Salter

Brachiopods

Lingulella ferruginea Salter
 Acrothele matthewi (Hartt)
 Acrotreta gemmula Matthew
 Acrotreta cf. gemmula Matthew

Micromitra (Iphidella) cf. ornatella (Linnarsson)
 Eorthis cf. papias (Walcott)

SPECIES FOUND IN THE PARADOXIDES
 HICKSI ZONE AT MANUELS

Trilobites

Paradoxides bennetti Salter
 Paradoxides cf. abenacus Matthew
 Paradoxides cf. efeminicus Matthew
 Paradoxides hicksi Salter
 Centrolepura venusta (Billings)

Conocoryphe æqualis Linnarsson
 Conocoryphe cf. æqualis (Hicks)

Brachiopods

Lingulella ferruginea Salter

Acrotreta socialis von Seebach
 Acrothyra comleyensis Cobbold

SPECIES FOUND IN THE PARADOXIDES
 HICKSI ZONE OF GREAT BRITAIN

Trilobites

Paradoxides bohemicus salopiensis Cobbold
 Paradoxides hicksi Salter

Paradoxides intermedius Cobbold
 Centrolepura pugnax Illing
 Centrolepura impar (Hicks)
 Centrolepura salteri (Hicks)
 Conocoryphe æqualis Linnarsson
 Conocoryphe bufo Hicks
 Conocoryphe cf. dalmani Angelin
 Conocoryphe homfroyi Hicks
 Conocoryphe perdita Hicks
 Liocephalus impressa (Linnarsson)
 Liostracus elegans Illing
 Liostracus lata Cobbold
 Liostracus dubia Cobbold

Liostracus globiceps jaculator, n. var.
Liostracus tener (Hartt)

Agraulos socialis Billings
Solenopleura cf. *applanata* (Salter)

Eodiscus punctatus (Salter)

Bailiella venulosa (Salter)

Agnostus gracilis Illing
Agnostus cf. *parvifrons* Linnarsson
Agnostus cf. *parvifrons* tessella Matthew
Agnostus cf. *nudus* (Beyrich)

Agnostus cf. *sulcatus* Illing
Agnostus barrandei Salter
Agnostus fissus Lundgren MS
Agnostus cf. *fallax* Linnarsson
Agnostus cf. *gibbus* Linnarsson
Agnostus cf. *gibbus* hybrida Brögger

Arionellus longicephalus Hicks
Agraulos cf. *holocephalus* Matthew
Solenopleura applanata (Salter)
Solenopleura variolaris (?) (Salter)
Corynexochus pusillus Illing
Corynexochus cambrensis Nicholas
Holocephalina incerta Illing
Hartshillia inflata Hicks
Dorypyge reticulata Cobbold
Dorypyge cf. *nichthofeni* Dames
Eodiscus punctatus (Salter)
Eodiscus punctatus scenicus (Linnarsson)
Bailiella venulosa (Salter)
Agnostus tuberculatus Illing
Agnostus triangulatus Illing
Agnostus gracilis Illing
Agnostus parvifrons Linnarsson
Agnostus nudus (Beyrich)
Agnostus regius globosus Illing
Agnostus integer (Beyrich)
Agnostus barlowi spinatus Illing
Agnostus sulcatus Illing
Agnostus corrugatus Illing
Agnostus barrandei Salter
Agnostus fissus Lundgren MS
Agnostus fallax Linnarsson
Agnostus cf. *intermedius* Tullberg
Agnostus punctuosus Angelin
Agnostus lobatus Illing

Agnostus granulatus (Barrande)
Agnostus cf. acadicus declivis Matthew
Agnostus rex (Barrande)
Agnostus lævigatus terranovicus Matthew
Agnostus lævigatus ciceroideus Matthew
Agnostus cf. umbo Matthew

Brachiopods

Lingulella ferruginea Salter
Acrothele cf. matthewi (Hartt)
Acrotreta misera (Billings)

Brachiopods

Agnostus typicalis Nicholas
Agnostus truncatus Brögger
Agnostus longifrons Nicholas
Agnostus cambrensis Hicks
Agnostus davidis Salter

Acrotreta sagittalis (Salter)

SPECIES FOUND IN THE PARADOXIDES DAVIDIS ZONE AT MANUELS

(The numbers in parentheses indicates the beds in which each species has been found.)

Trilobites

Paradoxides cf. hicksi (101)
Paradoxides davidis Salter (93?, 94-96, 100?, 101?, 111, 114-122, 124?, 125?)
Paradoxides rugulosus Corda (115, 116)
Centropleura pugnax Illing (99)

SPECIES FOUND IN THE PARADOXIDES DAVIDIS ZONE OF GREAT BRITAIN

Trilobites

Paradoxides rugulosus Corda
Centropleura impar (Hicks)
Centropleura pugnax Illing
Centropleura salteri (Hicks)

- Centropleura henrici* (Salter) (115)
Solenopleura cf. applanata (Salter) (99, 102, 105, 107-112)
Solenopleura variolaris (Salter) (115)
Solenopleura communis Billings (115)
- Centropleura henrici* (Salter)
Dorypyge cf. richthofeni Dames
Solenopleura cf. applanata (Salter)
Solenopleura variolaris (?) (Salter)
Liostracus pulchella Cobbold
Liostracus dubia Cobbold
Agraulos cf. holocephalus Matthew
Agraulos quadrangularis (Whitfield)
Ctenocephalus coronatus (Barrande)
Conocoryphe cf. dalmani Angelin
Holocephalina incerta Illing
Holocephalina primordialis Salter
Bailiella venulosa (Salter)
Carausia menevensis Hicks
Hartshillia inflata (Hicks)
Hartshillia spinata Illing
Corynexochus cambrensis Nicholas
- Eodiscus punctatus* (Salter)
Eodiscus punctatus scanicus Linnarsson
Agnostus cf. nathorsti Brögger
Agnostus glandiformis Angelin
Agnostus bifurcatus Illing
Agnostus kjerulfi Brögger
Agnostus cf. incertus Brögger
Agnostus nudus ovalis Illing
Agnostus altus Grönwall
Agnostus lens Grönwall
- Ctenocephalus coronatus* (Barrande) (Bed unknown)
Holocephalina primordialis Salter (115)
Bailiella venulosa (Salter) (109, 113)
Hartshillia inflata (Hicks) (111, 113)
Corynexochus minor (Walcott) (109, 116?, 119?)
Eodiscus punctatus (Salter) (99, 101-103, 106-109, 112, 115)
Agnostus vaningeni, n. sp. (99, 100, 102)
Agnostus bifurcatus Illing (Bed unknown)
Agnostus cf. kjerulfi Brögger (99-102, 105, 107, 109)
Agnostus cf. incertus Brögger (117)
Agnostus cf. nudus (Beyrich) (95, 99-101, 107, 109, 110)
Agnostus lævigatus ciceroides Matthew (93, 99, 102, 109, 110, 113, 115-120)
Agnostus lævigatus terranovicus Matthew (93, 94, 99, 109, 110, 113, 115-120)

Agnostus cf. *pusillus* Tullberg (110)
Agnostus cf. *planicauda* Angelin (Bed unknown)
Agnostus *barlowi* Belt (Bed unknown)
Agnostus cf. *umbo* Matthew (93)
Agnostus *gracilis* Illing (109)

Brachiopods

Obolus fragilis (Walcott) (109, 115)
Lingulella ferruginea Salter (101)
Acrotreta sagittalis (Salter) (Bed unknown)
Acrotreta misera (Billings) (99-109)

Brachiopods

Lingulella ferruginea Salter
Acrothele maculata (Salter)
Acrotreta sagittalis (Salter)
Billingsella cobboldi Matley
*Billingsella lindstroemi salopiensis** Matley
Billingsella hicksi (Salter MS)
Orbiculoidea pileolus (Hicks MS)

The detailed stratigraphic studies made by Mr. Illing on the Abbey Shales near Nuneaton, Warwickshire (Illing, 1914b; 1916), by Mr. Cobbold on the beds of Shropshire (Cobbold, 1911; 1913a; 1913b; 1921), and by Mr. Nicholas on those of Carnarvonshire (Nicholas, 1914; 1915; 1917), make possible a very detailed comparison of the trilobites of the Paradoxides faunas of those beds with the trilobites of the Paradoxides faunas at Manuels. The similarity of the ranges of the species of trilobites common to the Paradoxides beds of Manuels and Hartshill Hayes, Warwickshire, is shown in table VI (p 100). An examination of this table will disclose the fact that not only are most of the species of these two widely separated regions the same, but their ranges are very nearly the same. Such a correspondence as this has probably seldom been equalled in all geological time, and proves that England and Wales were in the same marine life province as southeastern Newfoundland in Paradoxidian times, and that there was a shallow water connection between them, through which the faunas could migrate.

COMPARISON OF THE PARADOXIDES FAUNAS OF THE MANUELS BROOK SECTION WITH THOSE OF SCANDINAVIA

The Paradoxides faunas of Scandinavia have been variously subdivided, but they can easily be grouped roughly into four main units, corresponding to the bennetti, hicksi, and davidis faunas, and a younger fauna, the Paradoxides forchhammeri fauna, which has not been recognized at Manuels. The bennetti, hicksi, and davidis faunas of Scandinavia are almost as much like those at Manuels as are the British ones. Their trilobites and brachionods are compared with those at Manuels in the columns below. As the division lines between the bennetti and hicksi zones, the hicksi and davidis zones, and the davidis and forchhammeri zones have been drawn at somewhat different places by different students of the Scandinavian Paradoxides beds, it is not always possible to determine from the literature from which of these zones a species has come, and some of the Scandinavian species in the following lists may, therefore, be wrongly placed.

SPECIES THAT HAVE BEEN RECOGNIZED IN THE PARADOXIDES BENNETTI ZONE
AT MANUELS

Trilobites

Paradoxides lamellatus Hartt

Paradoxides etemicus Matthew
Paradoxides bennetti Salter
Paradoxides parvulus, n. sp.

Hartella matthewi (Hartt)

Conocoryphe elegans (Hartt)
Conocoryphe bullata, n. sp.

Bailiella cf. baileyi (Hartt)
Ptychoparia cf. rogersi (Walcott)
Liostracus ouanagondianus (Hartt)
Liostracus tener (Hartt)

Agraulos cf. affinis Billings

Goniadiscus dawsoni (Hartt)

Agnostus cf. fallax trilobatus Matthew

Trilobites

Paradoxides ölandicus Sjögren
Paradoxides sjögreni Linnarsson

Paradoxides hicksi palpebrosus Brögger
Paradoxides aculeatus Linnarsson
Paradoxides jemtländicus Wiman

Hartella exsulans (Linnarsson)

Conocoryphe dalmani Angelin
Conocoryphe emarginata Linnarsson

Solenopleura cristata Linnarsson

Ellipsocephalus polymetopus Linnarsson

Agnostus regius Sjögren
Agnostus fallax Linnarsson
Agnostus gibbus Linnarsson var.
Agnostus atavus Tullberg

SPECIES FOUND IN THE PARADOXIDES
BENNETTI ZONE OF SCANDINAVIA

Agnostus granulatus (Barrande)
Agnostus cf. rex (Barrande)
Agnostus claræ, n. sp.
Agnostus barlowi definitus, n. var.
Agnostus cf. exaratus tenuis Illing

Brachiopods

Lingulella ferruginea Salter
Acrothele matthewi (Hartt)

Acrotreta gemmula Matthew
Acrotreta cf. gemmula Matthew

Micromitra (Iphidella) cf. ornatella (Linnarsson)
Eorthis cf. papias (Walcott)

SPECIES THAT HAVE BEEN FOUND IN THE PARADOXIDES HICKSI ZONE AT MANUELS

Trilobites

Paradoxides bennetti Salter ?
Paradoxides cf. eteminius Matthew
Paradoxides hicksi Salter
Paradoxides cf. abenacus Matthew
Centroleura venusta (Billings)

Brachiopods

Lingulella ferruginea Salter
Acrothele coriacea Linnarsson
Acrothele (Redlichella) granulata (Linnarsson)

Acrotreta schmalensei Walcott
Acrotreta socialis von Seebach

Billingsella exporrecta (Linnarsson)
Billingsella lindströmi (Linnarsson)

SPECIES FOUND IN THE PARADOXIDES HICKSI ZONE OF SCANDINAVIA

Trilobites

Paradoxides tessini Brongniart
Paradoxides hicksi Salter

Dorypyge oriens Grönwall

Dorypyge danica Grönwall
Corynexochus bornholmiensis Grönwall
Ptychoparia linnarssoni (Brögger)

Liostracus aculeatus Agnelin

Solenopleura parva Linnarsson

Bailiella breviceps (Ängelin)
Conocoryphe æqualis Linnarsson

Conocoryphe dalmani Ängelin
Conocoryphe tenuicincta Linnarsson
Conocoryphe latilimbata (Brögger)
Conocoryphe impressa Linnarsson
Hartella exulans (Linnarsson)
Liocephalus impressa Linnarsson
Liocephalus linnarssoni Grönwall
Ellipsocephalus granulatus Linnarsson
Ellipsocephalus muticus Ängelin
Eodiscus eucentrus (Linnarsson)
Eodiscus scanicus (Linnarsson)
Agnostus fallax Linnarsson
Agnostus fallax ferox Brögger
Agnostus parvifrons Linnarsson

Agnostus parvifrons mammillata Brögger
Agnostus barlowi Belt

Agnostus nudus scanicus Tullberg
Agnostus nudus marginatus Brögger
Agnostus rex (Barrande)
Agnostus intermedius Tullberg
Agnostus fissus Lundgren MS

Liostracus tener (Hartt)
Liostracus globiceps jaculator, n. sp.

Solenopleura cf. appplanata (Salter)

Agraulos socialis Billings
Bailiella venulosa (Salter)

Conocoryphe æqualis Linnarsson
Conocoryphe elegans (Hartt)

Eodiscus punctatus (Salter)

Agnostus cf. fallax Linnarsson

Agnostus cf. parvifrons Linnarsson
Agnostus cf. parvifrons tessella Matthew

Agnostus cf. nudus (Beyrich)

Agnostus rex (Barrande)

Agnostus fissus Lundgren MS

Agnostus cf. gibbus Linnarsson
 Agnostus cf. gibbus hybrida Brögger
 Agnostus cf. acadicus declivis Matthew
 Agnostus lævigatus ciceroideus Matthew
 Agnostus lævigatus terranovicus Matthew

Agnostus cf. sulcatus Illing

Agnostus gracilis Illing
 Agnostus barrandei Salter
 Agnostus granulatus (Barrande)
 Agnostus cf. umbo Matthew

Brachiopods

Lingulella ferruginea Salter
 Acrothele cf. matthewi (Hartt)

Acrotreta misera (Billings)

Agnostus fissus perrugatus Grönwall
 Agnostus gibbus Linnarsson
 Agnostus gibbus hybrida Brögger
 Agnostus exaratus Grönwall
 Agnostus pusillus Tullberg
 Agnostus altus Grönwall
 Agnostus lens Grönwall
 Agnostus lens frontosa Grönwall
 Agnostus rotundus Grönwall
 Agnostus incertus Brögger
 Agnostus truncatus Brögger

Agnostus nathorsti Brögger
 Agnostus punctuosus Angelin
 Agnostus atavus Tullberg

Brachiopods

Obolus schmalenseei (Walcott)
 Obolus (Westonia) finlandensis Walcott
 Lingulella ferruginea Salter

Acrothele coriacea Linnarsson
 Acrothele intermedia Linnarsson

Acrotreta sagittalis (Salter)
 Acrotreta schmalenseei Walcott

SPECIES THAT HAVE BEEN FOUND IN THE
PARADOXIDES DAVIDIS ZONE AT MANUELS

Trilobites

Paradoxides davidis Salter
Paradoxides rugulosus Corda

Centropleura pugnax Illing
Centropleura henrici Salter
Corynexochus minor (Walcott)

Bailiella venulosa (Salter)
Hartshillia inflata (Hicks)
Holocephalina primordialis Salter
Ctenocephalus coronatus (Barrande)

Solenopleura communis Billings

SPECIES FOUND IN THE PARADOXIDES
DAVIDIS ZONE OF SCANDINAVIA

Trilobites

Paradoxides davidis Salter
Paradoxides rugulosus Corda
Paradoxides tessini Brongniart
Paradoxides brachyrhachis Linnarsson

Corynexochus bornholmiensis Grönwall
Anomocare angelini Grönwall
Agrauios ceticephalus (Barrande)
Agrauios depressus Grönwall
Conocoryphe æqualis Linnarsson
Conocoryphe sulzeri (Schlotheim)
Bailiella breviceps (Angelin)
Bailiella venulosa (Salter)

Holocephalina primordialis Salter
Ctenocephalus tumida Grönwall

Conocephalites ornatus (Brögger)
Liostracus globiceps Grönwall
Liostracus aculeatus Angelin
Ptychoparia johnstrupi Grönwall
Ptychoparia Linnarssoni Brögger

Solenopleura brachymetopa Angelin
Solenopleura brachymetopa nuntia Grönwall
Solenopleura bucculenta Grönwall
Solenopleura canaliculata Angelin

- Solenopleura cf. applanata (Salter.)
 Solenopleura variolaris (Salter)
 Eodiscus punctatus (Salter)
- Agnostus cf. fallax Linnarsson
- Agnostus cf. incertus Brögger
 Agnostus cf. pusillus Tullberg
 Agnostus cf. nudus (Beyrich)
- Agnostus punctuosus Angelin
- Agnostus acadicus declivis Matthew
 Agnostus cf. exaratus tenuis Illing
- Agnostus cf. planicauda Angelin
 Agnostus parvifrons Linnarsson
 Agnostus cf. parvifrons mammillata Brögger
 Agnostus parvifrons punctifer, n. var.
- Agnostus granulatus (Barrande)
 Agnostus barlowi Belt
- Agnostus lævigatus terranovicus Matthew
 Agnostus lævigatus mamilla Matthew
 Agnostus lævigatus ciceroideus Matthew
- Agnostus kjerulfi Brögger
- Solenopleura holometopa Angelin
- Eodiscus eucentrus (Linnarsson)
 Agnostus elegans Tullberg
 Agnostus fallax Linnarsson
 Agnostus fallax ferox Tullberg
 Agnostus fallax tricuspidis Brögger
 Agnostus incertus Brögger
 Agnostus pusillus Tullberg
- Agnostus nudus scanicus Tullberg
 Agnostus nudus marginata Brögger
 Agnostus punctuosus Angelin
 Agnostus punctuosus affinis Brögger
 Agnostus punctuosus bipunctata Brögger
 Agnostus exaratus Grönwall
- Agnostus lundgreni Tullberg
 Agnostus lundgreni nana Grönwall
 Agnostus planicauda Angelin
 Agnostus parvifrons Linnarsson
 Agnostus parvifrons mammillata Brögger
- Agnostus parvifrons nepos Brögger
- Agnostus barlowi Belt
 Agnostus ferox Grönwall
 Agnostus lævigatus (Dalman)
- Agnostus rotundus Grönwall
 Agnostus altus Grönwall
 Agnostus insularis Grönwall
 Agnostus kjerulfi Brögger
 Agnostus lingula Grönwall

Agnostus sulcatus Illing

Agnostus gracilis Illing

Agnostus vaningeni, n. sp.

Agnostus bifurcatus Illing

Agnostus bibullatus (Barrande)

Agnostus cf. *fissus* perrugatus Grönwall

Agnostus rectangularis, n. sp.

Agnostus longifrons parvulus, n. var.

Agnostus rex (Barrande)

Agnostus cf. *umbo* Mathew

Brachiopods

Obolus fragilis (Walcott)

Acrotreta sagittalis (Salter)

Acrotreta misera (Billings)

Agnostus glandiformis resecta Grönwall

Agnostus nathorsti Brögger

Agnostus stenorrhachis Grönwall

Brachiopods

Acrothele coriacea Linnarsson

Acrotreta sagittalis (Salter)

SUMMARY

The Paradoxides beds at Manuels consist of 234 feet of hard, heavy-bedded greenish and bluish gray shales, with a few thin bands of light gray nodular limestone, overlaid by 68 feet of softer, thinner-bedded, dark gray and black shales, with occasional nodules, lenses, and thin beds of dark gray limestone. These beds contain great numbers of excellently preserved fossils. The fossils can be grouped in three main faunas, which may be called, after their most characteristic species of Paradoxides, the *Paradoxides bennetti*, *P. hicksi*, and *P. davidis* faunas. The oldest of these faunas, characterized by *Paradoxides bennetti*, occupies the lower 234 feet of the section. The next fauna, characterized by *P. hicksi*, occurs in the succeeding 37 feet. The third fauna, that of *P. davidis*, occupies the uppermost 31 feet. There is no sharp faunal break between any two of the three faunas, but each succeeding fauna differs from the one before it, because of the many new types introduced, as well as because of the dropping out of many of the old forms.

The lowest Paradoxides fauna is very different from the "*Metadoxides magnificus*" fauna found next below it. Some 10 feet of barren manganiferous shales intervene between the beds containing the two faunas, but it seems doubtful whether there exists any distinct stratigraphic break. The beds that immediately overlie the highest bed in which Paradoxides has been found are black shales which have yielded no good index fossils, so that their age is not known. They are succeeded by black shales containing *Agnostus pisiformis*, *Agnostus pisiformis obesus*, and other fossils characteristic of an "*Olenus*" fauna.

The Paradoxides faunas at Manuels may be closely correlated with those of Massachusetts, New Brunswick, and northwestern Europe. Faunas very similar to the *bennetti* fauna found at Manuels are known at Braintree (Massachusetts), near St. John (New Brunswick), in Great Britain,

and in Scandinavia; and slightly different, but closely related, faunas occur in southern France and the Spanish peninsula. Faunas very much like the hicksi fauna found at Manuels are known in Great Britain and Scandinavia, and a closely related fauna occurs in New Brunswick. Faunas very remarkably similar to the davidis fauna found at Manuels are known in Great Britain, Scandinavia, and Bohemia.

The close similarity between the Paradoxides faunas found at Manuels and those occurring in northwestern Europe is most remarkable, and has probably seldom been paralleled in all geological time. It proves that there must have been an open and easy marine highway between northeastern North America and northwestern Europe during most of known Paradoxidian time.

BIBLIOGRAPHY

- Angelin, N. P. 1878. *Palæontologia Scandinavica*. Pars I, Crustacea formationis transitionis, fasciculi 1 et 2. Holmiæ, 1878.
- Belt, T. 1868. On the "Lingula Flags," or "Festiniog Group" of the Dolgelly District, Part III. *Geol. Mag.*, vol. 5, 1868, pp. 5-7.
- Bergeron, J. 1889. Etude geologique du massif ancien situe au sud du plateau central. *Annales des Sciences Geologiques*, vol. 22, 1889.
- Beyrich, E. 1845. *Über einige böhmische Trilobiten*. Berlin, 1845.
- Billings, E. 1865. *Palæozoic Fossils*, vol. I. *Geol. Surv. Canada*, 1865.
- Billings, E. 1872. On some new fossils from the Primordial rocks of Newfoundland. *The Canadian Naturalist*, New Series, vol. 6, 1872, pp. 465-479.
- Billings, E. 1874. *Palæozoic Fossils*, vol. II, part I. *Geol. Surv. Canada*, Montreal, 1874.
- Brögger, W. C. 1878. On paradoxidesskifrene ved Krekling. Reprint from *Nyt Magazin for Naturvidenskaberne*, vol. 24, part 1, 1878.
- Buddington, A. F. 1914. Reconnaissance of the Algonkian rocks of southeast Newfoundland. *Bull. Geol. Soc. Amer.*, vol. 25, 1914, p. 40.
- Buddington, A. F. 1916. Pyrophyllitization, pinitization, and silicification of rocks around Conception Bay, Newfoundland. *Jour. Geol.*, vol. 24, No. 2, 1916, pp. 130-152.

- Budington, A. F. 1919. Pre-Cambrian rocks of southeast Newfoundland. Princeton University Contribution to the Geology of Newfoundland, No. 5. Jour. Geol., vol. 27, No. 6, 1919, pp. 449-479.
- Chamberlin, T. C. 1895. Notes on the glaciation of Newfoundland. Bull. Geol. Soc. America, vol. 6, 1895, p. 467.
- Cobbold, E. S. 1910. On some small trilobites from the Cambrian rocks of Comley (Shropshire). Quart. Jour. Geol. Soc. London, vol. 66, 1910, pp. 19-51.
- Cobbold, E. S. 1911. Trilobites from the Paradoxides beds of Comley (Shropshire). Quart. Jour. Geol. Soc. London, vol. 67, 1911, pp. 282-300.
- Cobbold, E. S. 1913a. The trilobite fauna of the Comley breccia bed (Shropshire). Quart. Jour. Geol. Soc. London, vol. 69, 1913, pp. 27-44.
- Cobbold, E. S. 1913b. Two species of Paradoxides from Neve's Castle (Shropshire). Quart. Jour. Geol. Soc. London, vol. 69, 1913, pp. 45-50.
- Cobbold, E. S. 1919. Cambrian Hyolithidæ, etc., from Hartshill in the Nunanton district, Warwickshire. Geol. Mag., dec. 6, vol. 6, 1919, pp. 149-158.
- Cobbold, E. S. 1921. The Cambrian Horizons of Comley (Shropshire) and their Brachiopoda, Pteropoda, Gasteropoda, etc. Quart. Jour. Geol. Soc. Lond., vol. 76, 1921, pp. 325-386.
- Dale, Nelson C. 1914. Manganese deposits of Conception and Trinity Bays, Newfoundland. Bull. Geol. Soc. Amer., vol. 25, 1914, pp. 73, 74.
- Dale, N. C. 1915. The Cambrian manganese deposits of Conception and Trinity Bays, Newfoundland. Princeton University Contribution to the Geology of Newfoundland, No. 2. Proc. Amer. Phil. Soc., vol. 54, 1915, pp. 371-456.
- Dawson, J. W. 1868. Acadian Geology, 2nd edition. London, 1868.
- Dawson, J. W. 1873. Annual address of the president of the Natural History Society of Montreal. The Canadian Naturalist, New Series, vol. 7, 1873, pp. 1-11.
- Etheridge, R. 1881. Anniversary address of the president of the Geological Society of London, 1881. Proc. of the Geol. Soc. of London for session 1880-81, pp. 37-235, in Quart. Jour. Geol. Soc. London, vol. 37, 1881.
- Frazer, Persifor, 1883. Geological notes in the several townships of Chester County. 2nd Geol. Survey of Pennsylvania. Report C4, the geology of Chester County, edited by J. P. Lesley, pp. 215-345, map. Harrisburg, 1883.
- Frech, F. 1897. Lethæa geognostica, theil 1, band 2, lieferung 1. Stuttgart, 1897.
- Grabau, A. W. 1900. Palæontology of the Cambrian Terranes of the Boston Basin. Occasional Papers of the Boston Soc. of Nat. Hist., IV, pp. 601-694, 1900.
- Grönwall, K. A. 1902. Bornholms Paradoxideslag og deres fauna. Danmarks Geol. Undersøgelse, II Række, No. 13. Copenhagen, 1902.
- Hawle, I., and Corda, A. J. C. 1847. Prodrum einer Monographie der böhmischen Trilobiten. Prague, 1847.

- Hayes, Albert O. 1914. Geology of the Wabana Iron Ore of Newfoundland. *Bull. Geol. Soc. America*, vol. 25, 1914, p. 74.
- Hayes, A. O. 1915. Wabana Iron Ore of Newfoundland. *Geol. Surv. Canada, Memoir 78*, No. 66, Geological Series; 1915.
- Hicks, H. 1872. On some undescribed fossils from the Menevian group. *Quart. Jour. Geol. Soc. London*, vol. 28, 1872, pp. 173-185.
- Howell, B. F. 1920a. Correlation of the Middle Cambrian of Newfoundland and Great Britain. *Bull. Geol. Soc. Amer.*, vol. 31, No. 1, 1920, p. 214.
- Howell, B. F. 1920b. The Middle Cambrian beds at Manuels, Newfoundland, and their relations. *Science, New Series*, vol. 51, No. 1330, 1920, p. 644.
- Howley, J. P. 1889. The Taconic of Eastern Newfoundland. *American Geologist*, vol. 4, 1889, pp. 121-125.
- Howley, J. P. 1907. Geological map of Newfoundland, compiled from the most recent and authentic sources, the coast line corrected to date from the admiralty surveys, the interior chiefly from the work of the geological survey, by James P. Howley, F. G. S., Director. 1907.
- Illing, V. C. 1913. Recent discoveries in the Stockingford Shales near Nuneaton. *Geol. Mag.*, dec. 5, vol. 10, 1913, pp. 452, 453.
- Illing, V. C. 1914a. Recent discoveries in the Stockingford Shales near Nuneaton. Report of the British Ass'n for the Adv. of Science, 1913 (Birmingham) meeting, 1914, pp. 498, 499.
- Illing, V. C. 1914b. The Paradoxidian fauna of a part of the Stockingford shales. *Geol. Mag.*, dec. 6, vol. 1, no. 8, 1914, pp. 379, 380.
- Illing, V. C. 1916. The Paradoxidian fauna of a part of the Stockingford shales. *Quart. Jour. Geol. Soc. London*, vol. 71 (for 1915), 1916, pp. 386-450.
- Jackson, C. T. 1859a. [On a Paradoxides from St. Mary's Bay, Newfoundland.] *Proc. Boston Soc. Nat. Hist.*, vol. 7, 1859, p. 54.
- Jackson, C. T. 1859b. [Comparison of specimens of Paradoxides from Braintree, Massachusetts, and St. Mary's Bay, Newfoundland.] *Proc. Boston Soc. Nat. Hist.*, vol. 7, 1859, p. 75.
- Jækel, O. 1909. Ueber die Agnostiden. *Zeitschr. der. Deutsch. geol. Gesell.* vol. 61. 1909, pp. 380-401.
- Jukes, J. B. 1839. Report on the geology of Newfoundland. St. John's, Newfoundland, 1839.
- Jukes, J. B. 1840a. Report on the geology of Newfoundland. *Edinburgh Phil. Jour.*, New Series, vol. 29, 1840, pp. 103-111.
- Jukes, J. B. 1840b. Report of the progress of the geological survey during 1840. St. John's Newfoundland, 1840.
- Jukes, J. B. 1842. Excursions in and about Newfoundland during the years 1839 and 1840. Two volumes. London, 1842.
- Jukes, J. B. 1843. General report of the geological survey of Newfoundland, executed under the direction of the government and legislature of the colony during the years 1839 and 1840. London, 1843.
- Keith, A. 1923. Cambrian succession of northwestern Vermont. *American Journal of Science*, 5th series, vol. 5, 1923, pp. 97-139.
- Lake, Philip. 1906. A monograph of the British Cambrian Trilobites, part I; 1906.

- Lapworth, C. 1891. On *Olenellus callavei* and its geological relationships. *Geol. Mag.*, dec. 3, vol. 7, No. 12, 1891, pp. 529-536.
- Linnarsson, J. G. O. 1869. Om Vestergöthlands Cambriska och Siluriska affagringar. *Kongl. Svenska Vetenskapsakademiens handlingar*. Band. 8, No. 2, 1869.
- Logan, W. E. 1865. Geological Survey of Canada. Report of progress from its commencement to 1863, atlas, 1865.
- Marcou, J. 1889. The Taconic of Eastern Newfoundland. *American Geologist*, vol. 4, 1889, pp. 121-125.
- Marcou, J. 1890a. The Lower and Middle Taconic of Europe and North America, I. *American Geologist*, vol. 5, 1890, pp. 356-375.
- Marcou, J. 1890b. The Lower and Middle Taconic of Europe and North America, II. *American Geologist*, vol. 6, 1890, pp. 78-102, 221-233.
- Matthew, G. F. 1865. On the Azoic and Palæozoic Rocks of Southern New Brunswick. *Quart. Jour. Geol. Soc. London*, vol. 21, 1865, pp. 422-434.
- Matthew, G. F. 1885. Illustrations of the fauna of the St. John group continued: on the *Conocoryphea*, with further remarks on Paradoxides. *Proc. and Trans. Roy. Soc. Canada for 1884*, vol. 2, sec. 4, 1885, pp. 99-124.
- Matthew, G. F. 1886a. Illustrations of the fauna of the St. John group continued, No. 3—Descriptions of new genera and species (including a description of a new species of *Solenopleura* by J. F. Whiteaves). *Proc. and Trans. Roy. Soc. Canada for 1885*, 1st ser., vol. 3, sec. 4, 1886, pp. 29-84.
- Matthew, G. F. 1886b. Abstract of a paper on the Cambrian faunas of Cape Breton and Newfoundland. *Canadian Record of Science*, vol. 2, 1886, no. 4, pp. 255-258.
- Matthew, G. F. 1887. On the Cambrian faunas of Cape Breton and Newfoundland. *Proc. and Trans. of the Roy. Soc. of Canada for 1886*, vol. 4, sec. 4, 1887, pp. 147-157.
- Matthew, G. F. 1888a. On a basal series of Cambrian rocks in Acadia. *Canadian Record of Science*, vol. 3, 1888, pp. 21-29.
- Matthew, G. F. 1888b. On *Psammichnites* and the early trilobites of the Cambrian rocks in eastern Canada. *American Geologist*, vol. 2, 1888, pp. 1-9.
- Matthew, G. F. 1888c. Illustrations of the fauna of the St. John Group. No. 4—Part 1, Description of a New Species of *Paradoxides* (*Paradoxides regina*). Part 2. The smaller trilobites with eyes (*Ptychoparidæ* and *Ellipsocephalidæ*). *Proc. and Trans. Roy. Soc. Canada for 1887*, vol. 5, sec. 4, 1888, pp. 115-166, pls. I-III.
- Matthew, G. F. 1888d. On the classification of the Cambrian rocks in Acadia. *Canadian Record of Science*, vol. 3, 1888, pp. 71-81.
- Matthew, G. F. 1890. On Cambrian Organisms in Acadia. *Proc. and Trans. Roy. Soc. Can. for 1889*, vol. 7, sec. 4, 1890, pp. 135-162.
- Matthew, G. F. 1891. On some causes which may have influenced the spread of the Cambrian faunas. *Can. Rec. Sci.*, vol. 4, 1891, pp. 255-269.
- Matthew, G. F. 1896. Faunas of the Paradoxides beds in eastern North America, No. 1. *Trans. N. Y. Acad. Sci.*, vol. 15, 1896, pp. 192-247.

- Matthew, G. F. 1899a. A Palæozoic terrane beneath the Cambrian. *Annals N. Y. Acad. Sci.*, vol. 12, No. 2, 1899, pp. 41-56.
- Matthew, G. F. 1899b. A new Cambrian trilobite. *Bull. Nat. Hist. Soc. New Brunswick*, No. 17, 1899, pp. 136-142.
- Matthew, G. F. 1899c. Studies on Cambrian faunas, No. 4—Fragments of the Cambrian faunas of Newfoundland. *Proc. and Trans. Roy. Soc. Canada for 1899*, 2nd ser., vol. 5, sec. 4, no. 3, 1899, pp. 67-95.
- Murchison, R. I. 1872. *Siluria*, 5th edition, London, 1872.
- Murray, Alexander, and Howley, James P. 1881a. *Geological Survey of Newfoundland*. London, 1881. [A re-publication of the Reports of Progress of the Geological Survey of Newfoundland for the years 1864 to 1879.]
- Murray, Alexander, and Howley, James P. 1881b. Map of the Peninsula of Avalon, showing distribution of formations. Scale, 4 miles to 1 inch. 1881.
- Nicholas, T. C. 1914. The trilobite fauna of the Middle Cambrian of the St. Tudwal's Peninsula (Carnarvonshire). *Geol. Mag.*, dec. 6, vol. 1, no. 8, 1914, p. 380.
- Nicholas, T. C. 1915. The geology of the St. Tudwal's Peninsula (Carnarvonshire). *Quart. Jour. Geol. Soc. London*, vol. 71, 1915, pp. 83-143.
- Nicholas, T. C. 1916. Notes on the Trilobite fauna of the Middle Cambrian of the St. Tudwal's Peninsula (Carnarvonshire). *Quart. Jour. Geol. Soc. London*, vol. 71, 1916, pp. 451-472.
- Peach, B. N. 1913. The relation between the Cambrian faunas of Scotland and North America. Report of the eighty-second meeting of the British Association for the Advancement of Science, Dundee, 1912, pp. 448-459; 1913.
- Perkins, G. H. 1908. Preliminary Report on the Geology of Franklin County. Report of the State Geologist on the Mineral Industries and Geology of Certain Areas of Vermont, 1907-1908; pp. 189-209; 1908.
- Raymond, P. E. 1913. Some changes in the names of genera of trilobites. Reprint from the *Ottawa Naturalist*, vol. 26, 1913, pp. 137-142.
- Raymond, P. E. 1914. Notes on the ontogeny of Paradoxides, with the description of a new species from Braintree. *Mass. Bull. Mus. Comp. Zool.*, Harvard, vol. 58, No. 4, 1914, pp. 225-244, 1 pl.
- Raymond, P. E. 1917. Beecher's classification of trilobites after twenty years. *Amer. Jour. Sci.*, 4th ser., vol. 43, 1917, pp. 196-210.
- Raymond, P. E. 1920. The pygidium of the trilobite. *Geol. Mag.*, vol. 57, 1920, pp. 22-25.
- Rogers, W. B. 1859. [Comparison of *Paradoxides bennetti* with *Paradoxides harlani*.] *Proc. Boston Soc. Nat. Hist.*, vol. 7, 1859, p. 86.
- Salter, J. W. 1859. On the fossils of the *Lingula*-flags or "Zone Primordiale." *Paradoxides* and *Conocephalus* from North America. *Quart. Jour. Geol. Soc. London*, vol. 15, 1859, pp. 551-555.
- Schuchert, C. 1910. Paleogeography of North America. *Bulletin of the Geological Society of America*, vol. 20, 1910, pp. 427-606, pls. 46-101.
- Tullberg, S. A. 1880. Om *Agnostus-arterna* de kambriska aflagrinn-

- garne vid Andrarum. Sveriges geol. undersökning, Ser. C, No. 42, 1880.
- Ulrich, E. O. 1911. Revision of the Paleozoic Systems. Bull. Geol. Soc. Amer., vol. 22, 1911, pp. 281-680.
- vanHise, C. R., and Leith, C. K. 1909. Pre-Cambrian geology of North America. U. S. Geol. Surv., Bull. No. 360, 1909.
- vanIngen, Gilbert. 1914a. Cambrian and Ordovician faunas of southeastern Newfoundland. Bull. Geol. Soc. Amer., vol. 25, 1914, p. 138.
- vanIngen, Gilbert. 1914b. Table of the Geological Formations of the Cambrian and Ordovician Systems about Conception and Trinity Bays, Newfoundland, and their Northeastern-American and Western-European Equivalents, based upon the 1912-1913 field work. Princeton, 1914.
- vonToll, E. 1899. Beiträge zur Kenntniss des Sibirischen Cambrium. I. Memoires de l'Academie Imperiale des Sciences de St. Petersburg, 8th Series, vol. 8, No. 10 et dernier, 1899, pp. I-IV, 1-57.
- vonZittel, K. A., and Eastman, C. R. 1913. Text-book of paleontology, vol. 1, 1913.
- Walcott, C. D. 1884. On the Cambrian faunas of North America, preliminary studies. U. S. Geol. Surv., Bull. No. 10, 1884.
- Walcott, C. D. 1887. Second contribution to the studies of the Cambrian faunas of North America. Bull. U. S. Geological Survey, No. 30, 1887. (Dated 1886, but said by Dr. Walcott, in Amer. Jour. of Science, 3rd ser., vol. 37, 1889, p. 377, footnote, not to have been issued until 1887).
- Walcott, C. D. 1888a. The Taconic system of Emmons and the use of the name Taconic in geologic nomenclature. Amer. Jour. of Sci., 3rd ser., vol. 35, 1888, pp. 229-242, 307-327, 394-401.
- Walcott, C. D. 1888b. The Stratigraphical Succession of the Cambrian Faunas in North America. Nature, vol. 38, 1888, p. 551.
- Walcott, C. D. 1889a. Stratigraphic position of the Olenellus fauna in North America and Eprope. Amer. Jour. Sci., 3rd ser., vol. 37, 1889, pp. 374-392; vol. 38, 1889, pp. 29-42.
- Walcott, C. D. 1889b. Description of new genera and species of fossils from the Middle Cambrian. Proc. U. S. Nat. Mus., vol. 11, 1889, pp. 441-446.
- Walcott, C. D. 1891a. The fauna of the Lower Cambrian or Olenellus zone. Tenth Annual Report of the U. S. Geol. Surv., part 1, pp. 509-774; 1891. (Report dated 1890, but not issued until 1891.)
- Walcott, C. D. 1891b. Correlation Papers—Cambrian. U. S. Geol. Surv., Bull. No. 81, 1891.
- Walcott, C. D. 1891c. [The stratigraphic succession of the Cambrian faunas in North America.] Congres geologique international, compte rendu de la 4me session, Londres, 1888, pp. 223-225; London, 1891.
- Walcott, C. D. 1891d. The North American continent during Cambrian time. Twelfth Annual Report of the Director of the U. S. Geol. Surv., Part I—Geology, pp. 523-568; 1891.
- Walcott, C. D. 1898. Cambrian Brachiopoda; Obolus and Lingulella, with description of new species. Proc. U. S. Nat. Mus., vol. 21, 1898, pp. 385-420.
- Walcott, C. D. 1899. Pre-Cambrian fossiliferous formations. Bull.

- Geol. Soc. Amer., vol. 10, 1899, pp. 199-244.
- Walcott, C. D. 1900a. Lower Cambrian terrane in the Atlantic Province. *Proc. Wash. Acad. Sci.*, vol. 1, 1900, pp. 301-339.
- Walcott, C. D. 1900b. Random, a Pre-Cambrian Upper Algonkian Terrane. *Bull. Geol. Soc. America*, vol. 11, 1900, pp. 3-5.
- Walcott, C. D. 1902. Cambrian Brachiopoda: *Acrotreta*; *Linnarssonella*; *Obolus*; with descriptions of new species. *Proc. U. S. Nat. Mus.*, vol. 25, 1902, pp. 577-612.
- Walcott, C. D. 1905. Cambrian Brachiopoda, with descriptions of new genera and species. *Proc. U. S. Nat. Mus.*, vol. 28, 1905, pp. 227-337.
- Walcott, C. D. 1910. Cambrian Geology and Paleontology, No. 6, *Olenellus* and other genera of the Mesonacidae. *Smithson. Misc. Coll.*, vol. 53, No. 6, 1910.
- Walcott, C. D. 1912. Cambrian Brachiopoda. *U. S. Geol. Surv.*, Monogr. 51; 1912.
- Walcott, C. D. 1916a. Cambrian Geology and Paleontology, III, No. 3, Cambrian Trilobites. *Smithson. Misc. Coll.*, vol. 64, No. 3; 1916.
- Walcott, C. D. 1916b. Cambrian Geology and Paleontology, III, No. 5, Cambrian Trilobites. *Smithson. Misc. Coll.*, vol. 64, No. 5; 1916.
- Walcott, C. D. 1920. Cambrian Geology and Paleontology IV, No. 6—Middle Cambrian Spongiae. *Smithson. Misc. Colls.*, vol. 67, No. 6, pp. 261-338; 1920.
- Weston, T. C. 1896. Notes on the geology of Newfoundland. *Proceedings and Transactions of the Nova Scotia Institute of Science*, vol. 9, 1896, pp. 150-157.
- Whiteaves, J. F. 1878. On some Primordial Fossils from South-eastern Newfoundland. *Amer. Jour. Sci.*, 3rd ser., vol. 16, 1878, pp. 224-226.
- Willis, B. 1912. Index to the Stratigraphy of North America. *U. S. Geol. Surv.*, Professional Paper 71; 1912.

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